SMALL PARTS COUNTING AND BAGGING DEVICE

Team HandiCats

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10 June 2009

Abstract

The need for the project was to assist people with disabilities in the workplace. Team HandiCats worked with Tri-State Industries to enhance the process of counting and bagging small parts. The following report contains the need, benchmarking, concept generation, and concept selection for the project. It also includes the design development and testing, design refinement, final design description, and conclusions.

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1.0 Introduction

Team members are enrolled in the Senior Design course for Mechanical Engineering. This year-long course is a ". . . three course sequence that will provide a comprehensive, capstone, senior design experience for mechanical engineering majors. [The] course includes studies in the analytical techniques of design, as well as the design, construction, and evaluation of the performance of an actual engineering system" (Kremer, 2008). The project for the 2008-2009 class is to design and build a device to assist people with disabilities in the workplace in accordance with the NISH competition guidelines.

1.0.1 Background Information

"Around 10 percent of the world's population, or 650 million people, live with disabilities. . . However, all over the world, persons with disabilities continue to face barriers to their participation in society and are often forced to live on the margins of society" (UN Enable, 2008). There will always be people with disabilities and much advancement has been made to make their lives a little easier and enable them to perform better in the workplace. Even with these advancements, such as handicapped parking, the No Child Left Behind Act of 2001, and powered wheelchairs, people with disabilities will continuously struggle with performing simple tasks at work. Every device made ensures an easier work day for these people.

People with disabilities often want to work or need to work but have many obstacles that keep them from getting hired. Some of these include "Inadequate training" and "Discouraged from working by family and friends", but the largest being "No appropriate jobs available" (US DoL, 2008). Jobs for people with disabilities need to be simple and within their limits, but also need to push their capabilities.

The National Industries for the Severely Handicapped (or NISH) is an organization dedicated to helping these people. As defined by the organization (NISH, 2008):

> NISH is a national nonprofit agency whose mission is to create employment opportunities for people with severe disabilities by securing Federal contracts through the AbilityOne Program, formerly Javits-Wagner-O'Day (JWOD), for its network of community-based, nonprofit agencies. Providing employment opportunities to more than 40,000 people, the AbilityOne Program is the largest single source of employment for people who are blind or have other severe disabilities in the United States. More than 600 participating nonprofit organizations employ these individuals and provide quality goods and services to the Federal Government at a fair price.

1.0.2 Purpose of Project

People with disabilities often have the same or greater desire to contribute in the workplace as those without disabilities; however, these individuals are often unable to perform even simple tasks due to their disabilities. For this reason, assistive technologies are needed to allow people with disabilities to perform more naturally in the workplace. According to the 2007 Disability Status Report, people with disabilities account for approximately 21.2 percent of "working age people" who are currently working. This suggests that the need for assistive technologies is widespread among the workforce.

The purpose of this senior design project is to develop a technology to allow people with moderate to severe disabilities to successfully perform simple tasks in the workplace.

1.0.3 Scope of the Work

The scope of this project is to design, build, and analyze a system that will assist people with disabilities working in the Southern Ohio region. The team will have direct contact with the customer in order to obtain their ideas, suggestions, and comments throughout the completion of the project. Once the project is complete, our customer will have a functioning device. The team will meet the budget allotted in addition to the NISH competition deadlines.

1.0.4 Goals/Objectives

The goals/objectives of the project are shown below:

1. Assist people with disabilities in the workplace
2. Learn how to both manage and lead a team
3. Effectively use project management tools
4. Perform background research and benchmarking in order to acquire the information needed to understand the problem and possible solutions
5. Work with customers to fulfill a need
6. Design and build a functioning prototype
7. Effectively document and present pertinent information to both Dr. Kremer and the class
8. Submit a completed application and design report to the NISH competition
9. Remain within budget and on schedule for the duration of the project

1.1 Initial Needs Statement

According to the NISH competition (paraphrased here) the initial needs statement is:

> There is a need for creative technology that will assist individuals with disabilities to advance in or even enter the workplace. These disabilities may include varying levels of

physical handicaps or lowered mental functionality. The solution may address the disability directly or through indirect means such as adapting their environment.

1.1.1 Tri-State Industries

Tri-State Industries is a non-profit organization that provides people with disabilities meaningful work experience. Tri-State's mission statement is:

> Our mission is to assist our employees in the development and implementation of employment opportunities and related services as well as provide quality work services and products for our business customers.

Currently the disabled employees, also known as "consumers", have difficulty in counting and bagging small parts such as bolts, nuts, and washers.

2.0 Customer Needs Assessment

The HandiCats decided that in order to voice the true needs of the customer, it was necessary to make several trips to visit the facility and speak with both the supervisors and the workers themselves. The customer, Tri-State Industries, employs people with disabilities to work as consumers. Through several visits of observation, as well as phone calls, the HandiCats were able to create an initial list of customer needs. These needs, shown below in Table 2.0.1, are driven by the voice of the supervisors and consumers at Tri-State, as well as by team discussions.

Table 2.0.1 - Initial Customer Needs Determined by Both Customer and Team

Size
Quality Control
Ease of Use
Low Maintenance
Adaptable
Productivity
Moveable
Safe
Cost

This initial set of customer needs led to the following needs statement:

> There is a need for the advancement of jigs to assist in the counting and bagging of nuts, bolts, and washers for employees with physical and/or mental disabilities.

After discussing the initial customer needs list with the customer, it was determined that all of the included needs should remain on the list. In addition, the supervisor and consumers thought that aesthetics should be placed on the list.

2.1 Weighting of Customer Needs

Although all the customer needs are important, their levels of importance vary greatly. For this reason, the team assigned an initial weight factor to each of the ten needs. The needs were first ranked in order from 1 to 10 (with 1 being the most important, and 10 being the least important). Weightings were then assigned based on the rankings. Table 2.1.1 shows the weighting of the needs based on team evaluations.

Table 2.1.1 - Team's Weight Factors of Customer Needs

Customer Need	Weight Factor
Safety	0.18
Ergonomics	0.18
Quality Control	0.15
Productivity	0.15
Adaptability	0.10
Cost	0.08
Size	0.05
Sustainability	0.05
Mobility	0.03
Aesthetics	0.03

The survey shown in Figure 2.1.1 was given to Tri-State in order to determine the customer's evaluation of the needs. The team's rankings were given to the customer, such that the customer could see what needs the team felt were most important.

Part of our process is to access the needs of the project and rank them in order of importance, so that we can focus our attention appropriately. We have considered the needs and ranked them to the best of our abilities, as you can see on the far right side of the table below. We would like to ask that you also rank the following needs in order of importance (1 being the most important, 10 being the least important). Please save your changes and email this back to me at your earliest convenience. Also feel free to contact me with any questions. Thank you in advance!

NEED	Tri-State's RANKING	Team's RANKING
Safety	1	1
Ergonomics • ease of use for consumers	2	2
Quality Control • ability to reduce error	3	3
Productivity • rate of production	4	4
Adaptability • ability to work with multiple materials, sizes and quantities	5	5
Cost	6	6
Size	9	7
Sustainability • low maintenance	8	8
Mobility • ability to be easily moved	7	9
Aesthetics • attractiveness to consumers	10	10

Figure 2.1.1 - Customer Needs Survey

Using the customer's ranking of the needs (See Figure 2.1.1), in addition to the team's evaluations of the needs, an AHP Pair Wise Comparison Chart was created. This chart, which can be found in Appendix A as Table A.1, assisted the team in determining the new weightings seen below in Table 2.1.2.

Table 2.1.2 - Collaborative Weight Factors of Customer Needs

Customer Need	Weight Factor
Safety	0.18
Ergonomics	0.16
Quality Control	0.16
Productivity	0.15
Adaptability	0.09
Cost	0.08
Size	0.05
Sustainability	0.05
Mobility	0.03
Aesthetics	0.03

Table 2.1.3 shows the hierarchal list of each individual customer need, including its collaborative weighting.

Table 2.1.3 - Hierarchal Customer Needs List

1. Safety (0.18)
   1.1 No sharp edges, pinch points, quick movements or sticking
2. Ergonomics (0.16)
   2.1 Improve quality of work for current consumers
   2.2 Allow additional consumers to perform tasks
3. Quality Control (0.16)
   3.1 Must not generate additional error
4. Productivity (0.15)
   4.1 Improve or maintain productivity for Tri-State
5. Adaptability (0.09)
   5.1 Can be adapted to different sizes/shapes of parts
   5.2 Can be used with parts of different materials
6. Cost (0.08)
   6.1 Inexpensive to produce and reproduce
7. Mobility (0.05)
   7.1 Lightweight
   7.2 Able to be locked down
8. Sustainability (0.05)
   8.1 Low maintenance
   8.2 Able to withstand factory settings
9. Size (0.03)
   9.1 Size appropriate for work space
10. Aesthetics (0.03)
    10.1 Attractive for consumers to use

2.2 Revised Needs Statement

Discussion with the customer also led to the determination that the primary focus of the project should be the ease of the system, with a secondary focus on the quality of work. In order to encompass these focal points, the needs statement was rewritten as:

> Tri-State Industries has a need for an improved system to increase the ease of and quality of work in the counting and bagging of nuts, bolts and washers performed by their employees, also called consumers, with mental and/or physical disabilities. The main focus is ergonomics of the system, such that severely disabled employees who are currently unable to participate in the work will be able to use the system.

3.0 Benchmarking, Standards and Target Specifications

3.1 Benchmarking

Commercially available products already exist for the purpose of counting small items. One of which is a tablet counter used in pharmacies. A large amount of tablets and pills can be dropped onto a tray and the machine will release the desired amount of tablets (Farma, 2008). This design concept could be used in the application of small hardware. Bolts, nuts, and washers are about the same size and shape of tablets. This system is shown in Figure 3.1.1.

Figure 3.1.1 - Pill Counter (Farma, 2008)

Another automatic Counting machine is the "Candy, Nut and Tablet Counting and Packing Machine." This machine can automatically sort and count parts as well as fill and seal bags. This machine can pack one to ten kinds of different hardware parts into one bag. It can pack all kinds of small regular or irregular hardware and plastic products, such as nails, nuts, bolts and electronics (ECplaza, 2008). This machine would make the entire process automatic, accurate and fast (shown in Figure 3.1.2).

Figure 3.1.2 - "Candy, Nut and Tablet Counting and Packing Machine" (ECplaza, 2008)

Unfortunately, machines such as these would be very expensive to design and build or buy off the shelf. While the underlying concepts can aid the design process, a simpler system is needed in this case. The following table (Table 3.1.1) uses numbers 1-3 to rate each feature as good to bad; 1 being good, 3 being bad and 2 being moderate.

Table 3.1.1 - Benchmarking of Products

Feature	**Tablet Counter**	**Counting and Packing Machine**
Size	2	3
Weight	2	3
Cost	3	3
Flexibility	3	2
Quality Control	1	1
Ergonomics	1	1
Sustainability	2	3
Productivity	1	1
Moveable but able to be secured	2	3
Safe to operate	2	3
TOTALS	**19**	**23**

Note: the lower the number, the better the choice. The best option between these products is the tablet counter because of its simpler nature. However, an even simpler device has the potential to be far more suitable for our customer needs.

There are other types of counting machines that would not work for our customer, but the technology should also be taken into consideration. For example, money counting machines serve a similar purpose (see Figures 3.1.3 and 3.1.4). Some machines can count bills, while other machines can count coins. However, the coin counting machines would be inappropriate for our customers needs because of the size and shape of the hardware used (Ribao, 2008).

Figure 3.1.3 – Heavy Duty Coin Counter with Automatic Feeding Hopper (Ribao, 2008)

Figure 3.1.4 – Coin Sorter (Ribao, 2008)

3.2 Standards

As indicated in the features column we would like this device to be moveable, but be able to secure it to the table. To be movable we should follow standards for how much weight a person in the workplace should be expected to lift. According to research there is no standard from The Occupational Health and Safety Regulation (OSHA) that has a maximum weight limit (Fairfax, 2008). The National Institute for Occupational Safety and Health (NIOSH) has developed a mathematical model that helps predict the risk of injury based on the weight being lifted (Fairfax,

2008). This accounts for many confounding factors. Regulations only require a task be assessed when there is a significant risk of Musculoskeletal Injury (MSI). Considering our design will not be lifted very often and it does not have to be moved by the employees with disabilities, the NIOSH model is too elaborate for our circumstances. We should be able to make it manageable for one person to move without assistance. The production manger said it should not weigh more than then 10lb. We will use this as our target specification.

3.3 Target Specifications, Constraints and Design Criteria

We translated the customer requirements and engineering standards to target specifications, constraints, and design criteria in a number of steps. We first went to Tri-State to ask the supervisors what they needed and looked at the process. Unfortunately, during our first visit the employees were not present so we could not supervise their work. We did however come away with a good, basic understanding of the process and began to develop their needs as laid out in Table 2.1.1.

We met as a team to discuss goals that we thought we should include as well. After meeting we came up with an initial list of target specifications that highlighted all the needs, but did not quantify everything.

We went back to Tri-State a second time to observe the consumers at work to try to get a more detailed understanding of their needs. We asked them questions and watched them work. We did time trails to see how long it would take different consumers with different abilities to do different tasks. The supervisor and the production manager for this process were also consulted to get quantitative target specifications.

After our second visit we met as a team to finalize and quantify all the design criteria and target specifications.

Our design criteria and specifications are as follows:

Table 3.3.1: Target Specifications Based on Customer Feedback

	Customer Specification
Size	≥4 stations per 3’ x 8’ table
Accuracy	<1% error
Simplicity and Ease of Operation	1. Usual workers can operate with minor training 2. Open job to new workers previously unable to do work
Life Expectancy	5 years before any maintenance inspection
Easy Maintenance	<1 year maintenance experience needed
Adaptability	Metal or Plastic ≤1” bolt size ≤50 parts able to be counted
Production Rate	*Target Spec*: 15.6 parts/min *Design Criteria*: 50 parts/min
Weight	<10 lbs
Safety	No sharp corners or edges, pinch points, quick movements, or unintended sticking within any moving parts
Ergonomics	Workers must be comfortable when using. (Based on employee feedback)
Aesthetics	Increase workers’ focus
Cost	<$100 per device

4.0 Concept Generation

4.1 Problem Clarification

One of the jobs of Tri-State Industries is to count and bag bolts, nuts, and washers. These parts vary between plastic and metal as well as in size and quantity per order. Each order also varies in its total size. In other words, the entire order may take months to fill, or it may take a year or more to fill. However, the employees, or consumers as they are referred to at Tri-State, have difficulties counting to the specified quantity. Therefore, simple wooden jigs were fashioned to facilitate the process.

Figure 4.1.1 – Example of bolts, washer, and nut handle by workers

Figure 4.1.2 – Wooden jigs originally in use to fill orders

The jig in the lower left hand corner of Figure 4.1.2 is currently used to fill an order of 32 bolts per bag. The consumers place one bolt into each hole until all the holes are filled. Once they are all filled, the consumers then flip the jig over to deposit the bolts into a larger bag. The bolts are then poured out of the larger bag into a smaller bag for shipping. Some consumers even pull each part back out of the jigs, one-by-one and place them into the smaller bag. A similar process is followed for the nuts and washers. The jig in the upper left hand corner of Figure 4.1.2 is used to fill the same order of 32 parts per bag, but this time for the nuts and washers. The only difference here is that the nuts and washers are placed onto the pegs in the board. The jig is then flipped over to deposit the nuts or washers into the larger bag, only to be transferred into a

smaller bag (or the parts are removed part by part).

It is then up to the supervisor to manually check each bag before shipment to assure it has the correct number of parts. If there is a mis-quantity, the supervisor must fix the problem by either adding or removing parts. Although the customer receiving the parts only requires Tri-State to perform a check for every 1-in-13 bags, the supervisors at Tri-State feel that that leaves too much error. While the Tri-State employees are capable of greater accuracy, it greatly depends on their mood each day. Therefore, there is little to no consistency, leaving such a mechanical check (of 1-in-13 bags) ineffectual.

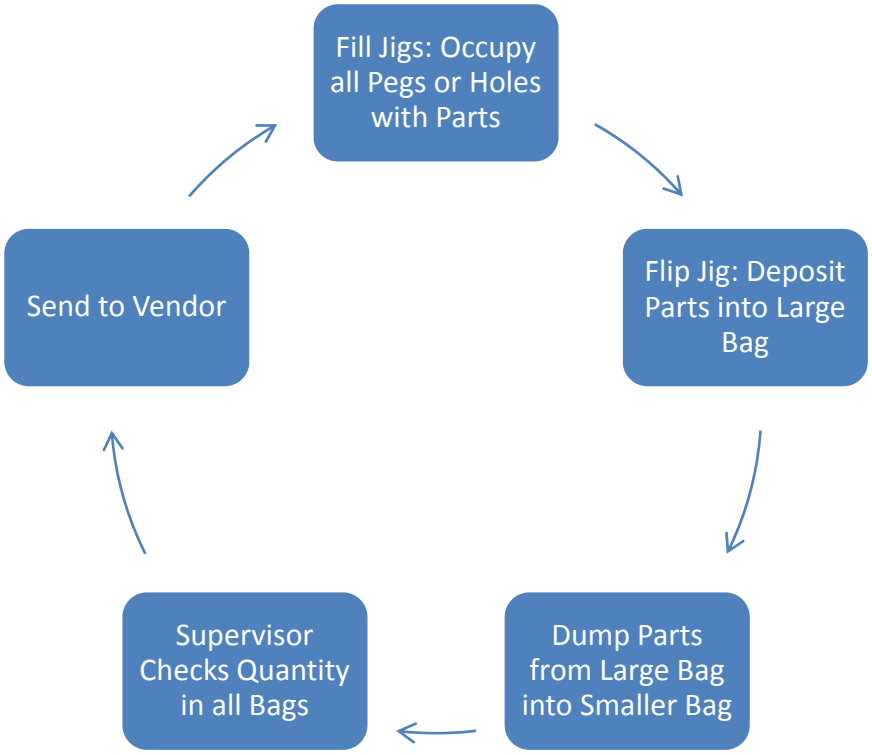
Fill Jigs: Occupy all Pegs or Holes with Parts
Flip Jig: Deposit Parts into Large Bag
Dump Parts from Large Bag into Smaller Bag
Supervisor Checks Quantity in all Bags
Send to Vendor

Figure 4.1.3 – Small parts counting and bagging process flow chart

Unfortunately, the current process is tedious and difficult or impossible for the employees with limited range of motion or low mental functionality. Only a few of the employees are currently able to accomplish the larger orders because they have a greater range of motion and ability to count to larger numbers. Process errors and delays occur when the employees become distracted or have difficulty removing the parts from the current equipment. These failure modes call for a device that can keep the user's attention, requires little input force or degree of motion from the user, and is simple to use for even the lower mental functioning workers.

Furthermore, the work area used to fill these orders is relatively small and therefore restricts the size of apparatus that can be considered (see Figure 4.1.4).

Figure 4.1.4 – Workspace allotted to the process of bolts, nuts, and washers

4.2 Patent Searching

The following are patents that were used during the concept generating phase of the design process. Although none are directly applicable, the concepts behind their operations are good to keep in mind while generating concepts of our own.

1. "Tablet Counting and Batching Machines," U.S. Patent #2,781,947 (See Figure 4.2.1), specifically details one method for delivering a predetermined number of tablets into a packaging container. This method uses differential air pressure (either suction or air pressure) to replace a physical gate that would allow or restrict the movement of tablets through a chute.

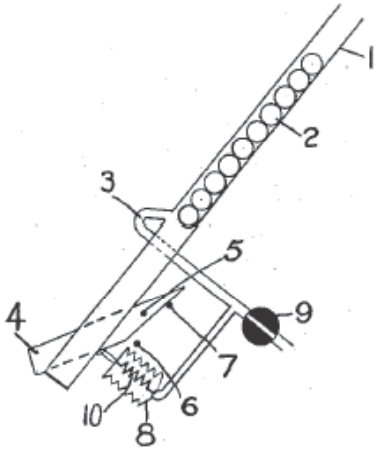

Figure 4.2.1 – Gate system to control flow of tablets through a chute

2. "Article Counting Machine with Automatic Control of Discharge Assistant," U.S. Patent

#3,384,269 (See Figure 4.2.2), details a method to automatically count cylindrical parts. The system uses a specially designed gear to collect one rod at a time and deposit it into a trough. The rotational speed of the gear can be varied to control the speed of discharge. The rotation activates a clicker that mechanically keeps track of the number of parts.

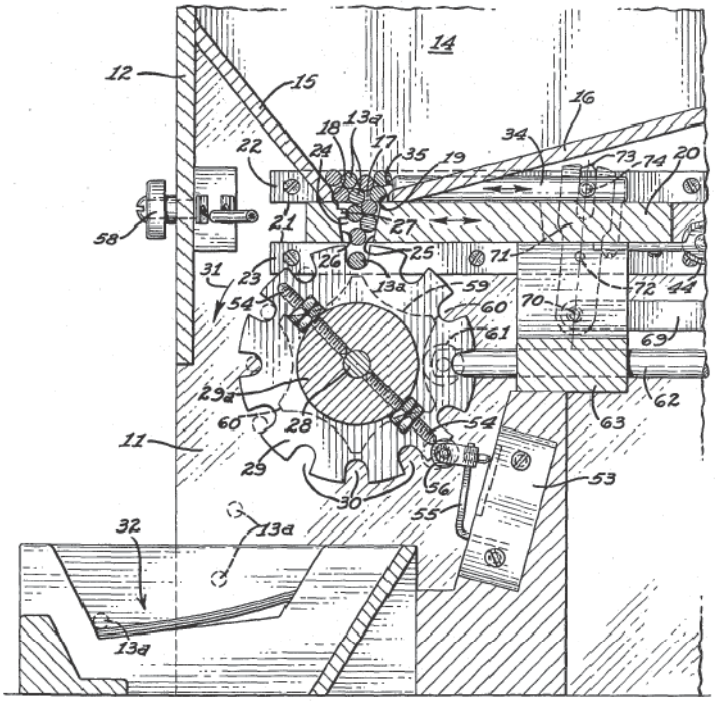

Figure 4.2.2 – Automatic system to count cylindrical rods

3. "Sorting Machine," U.S. Patent #2,156,822 (See Figures 4.2.3 and 4.2.4), details a sorting machine that first gauges the acceptability of bolts. The machine then accepts correctly dimensioned parts or discards incorrect parts. The important concept pulled from this patent was the method of transporting bolts down the line.

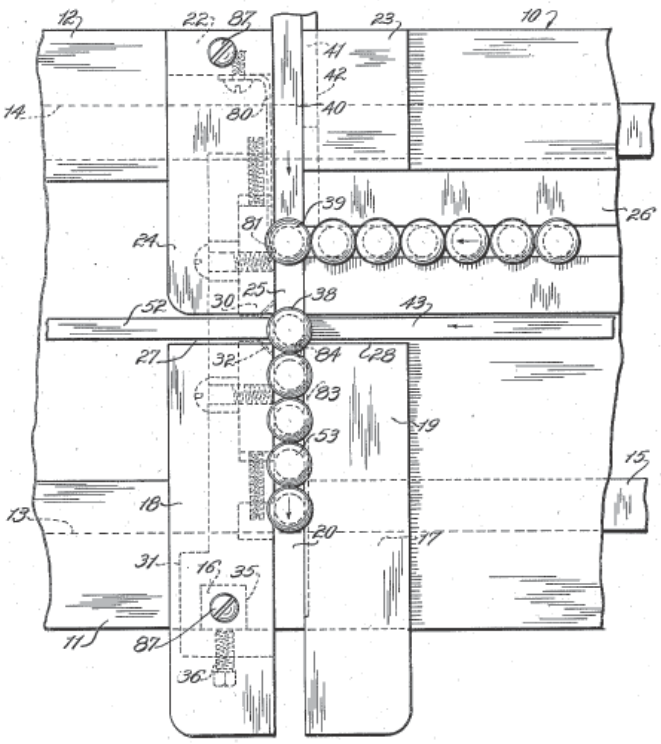

Figure 4.2.3 – Top View of Bolt Sorting and Gauging Machine

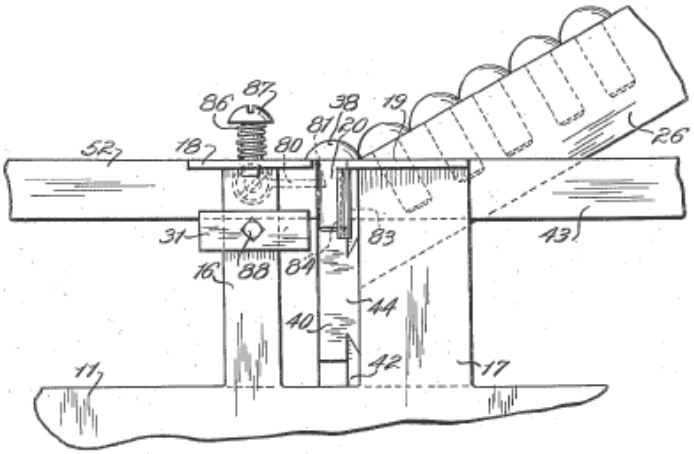

Figure 4.2.4 – Side View of Bolt Sorting and Gauging Machine

4. "Sorting Machine," U.S. Patent #6,787,724 (See Figures 4.2.5, 4.2.6, 4.2.7, and 4.2.8) details a method for aligning, transporting, and rejecting dimensionally inaccurate parts. This patent details several concepts could be used to satisfy our customer needs, including the ability to automatically orient parts, transport parts through a system, and for depositing parts.

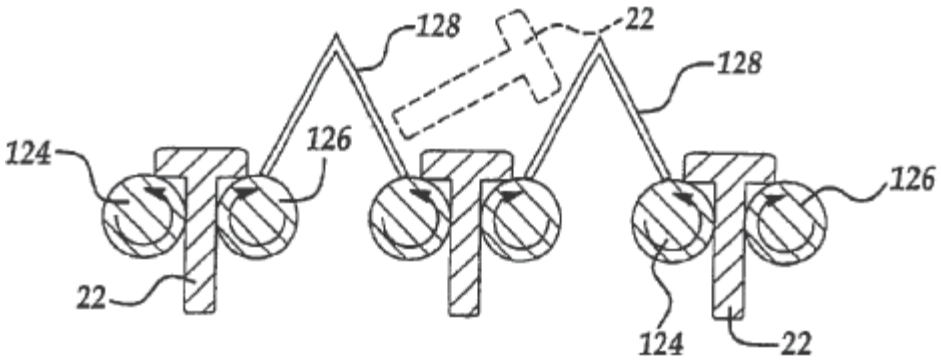

Figure 4.2.5 – Method to Align Fasteners for further processing

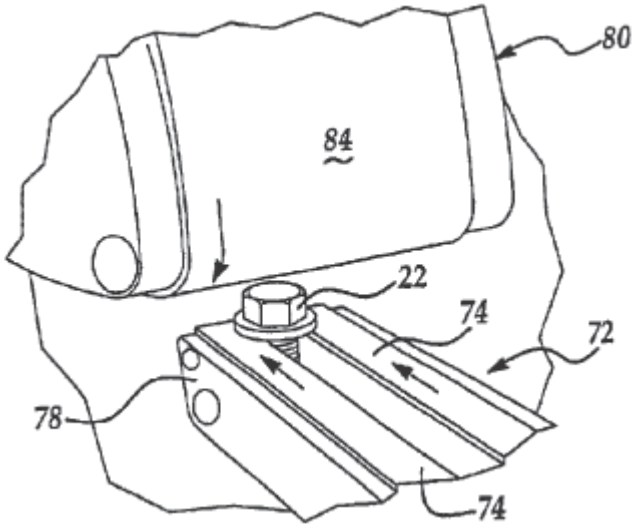

Figure 4.2.6 – Fastener Transportation Method

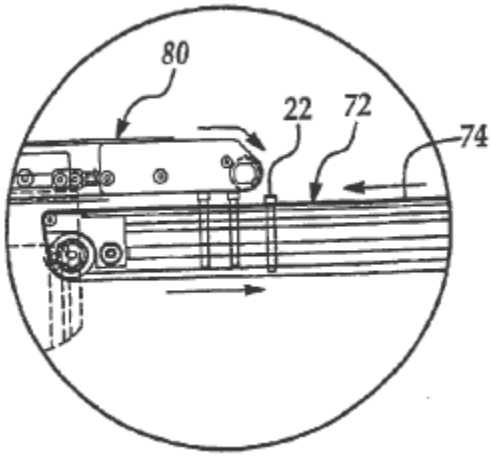

Figure 4.2.7 – Continued Fastener Transportation using Magnetized Conveyer

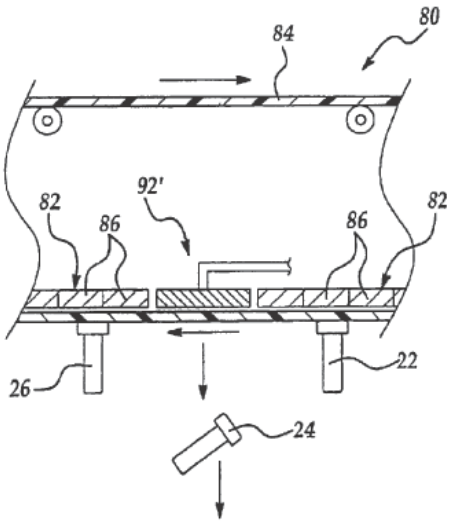

Figure 4.2.8 – Rejection System for Inaccurate Fasteners across Magnetized Conveyer

5. "Nut Sorting Machine," U.S. Patent #3,613,882 (See Figure 4.2.9), details a method for sorting different sized nuts. This method would allow a wide range of differently sized nuts or washers to be counted without modification from the Tri-State employees.

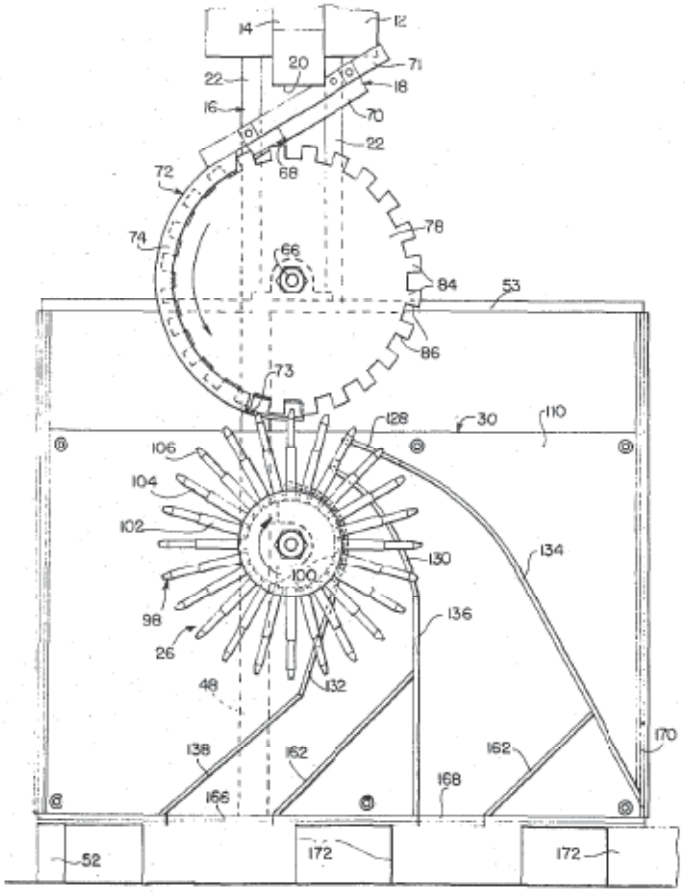

Figure 4.2.9 – Nut Sorting Machine

4.3 Concept Generation

Brainstorming was done outside of group meetings by each team member. Then meetings would be held to present each idea. During these sessions, ideas were explained then dissected and analyzed by other teammates. *In depth detail was not generated during this period*. Rather, by allowing other members to question design ideas and brainstorm possible alternatives to general features, refined concepts were created. A total of seven concepts have been advanced from preliminary brainstorming sessions. These are displayed below along with a description of the operation. Each of these concepts has been evaluated as to whether they meet our customer's requirements and our target specifications. This will be discussed in section 5.

4.3.1 Concept A: Rotating Devices

This idea involves slots and rods that are filled with bolts and nuts/washers respectively, up to a certain length. When the slots or rods have been filled completely the correct quantity has been achieved. The device is then rotated so that the parts fall into a bagging device (not shown). This can be seen in Figures 4.3.1 and 4.3.2. This idea would require that both ideas be made to satisfy each order independently. Therefore, the slots and rods would be removable so that different quantities and sizes of parts can be processed.

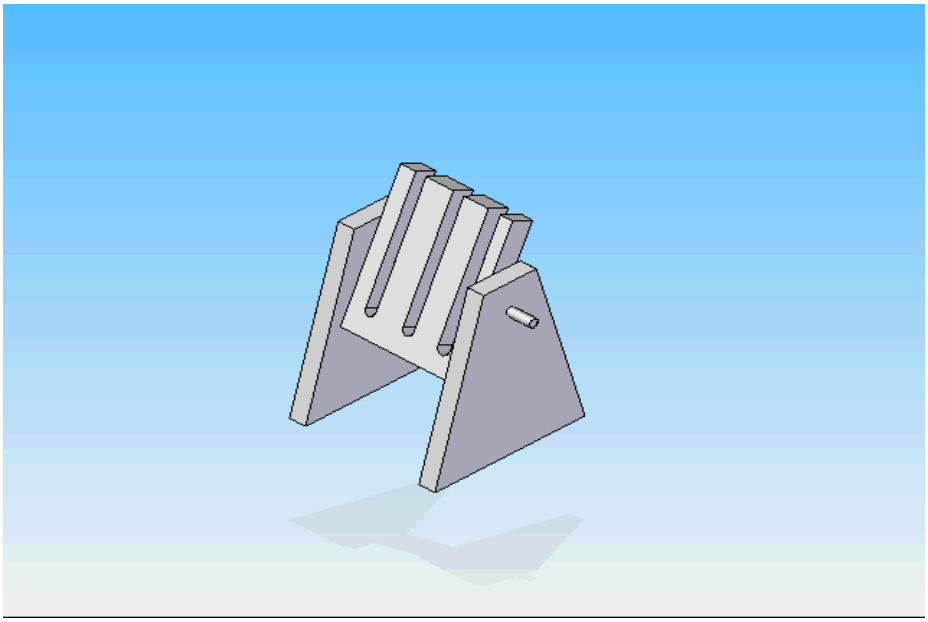

Figure 4.3.1 – Slotted device for bolts

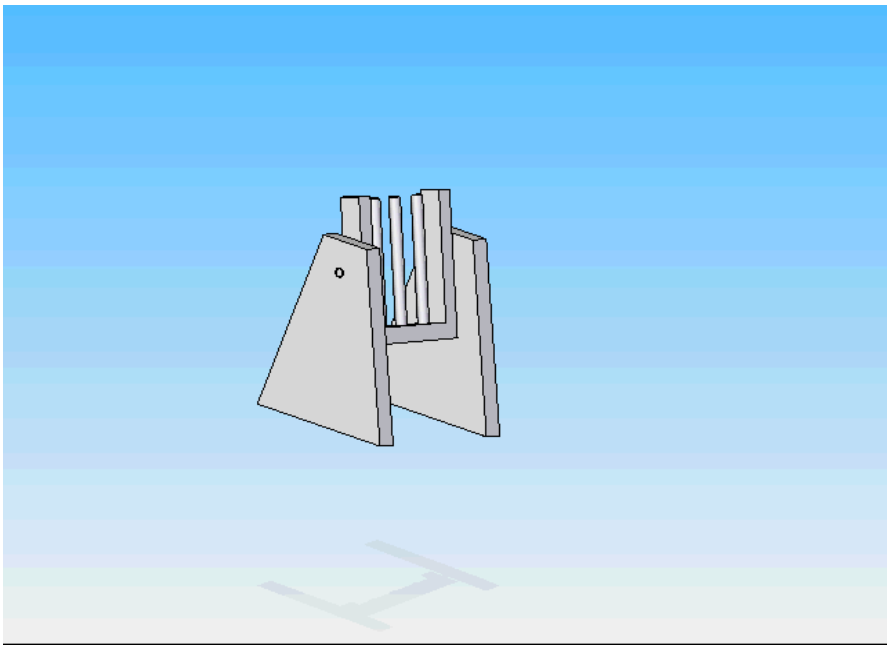

Figure 4.3.2 – Rods for nuts and washers

4.3.2 Concept B: Drop Plate

This idea consists of an angled bread board with 50 holes that is set against a solid plate. The holes are one inch in diameter to allow a variety of parts to be counted with one device. When all the holes are full the operator pulls a lever or pushes on handles that will depress the back plate and separate it from the front. Because the plate is at an angle the parts will fall back and through the device and into a funnel that will bag the parts. This idea is shown in Figures 4.3.3 and 4.3.4.

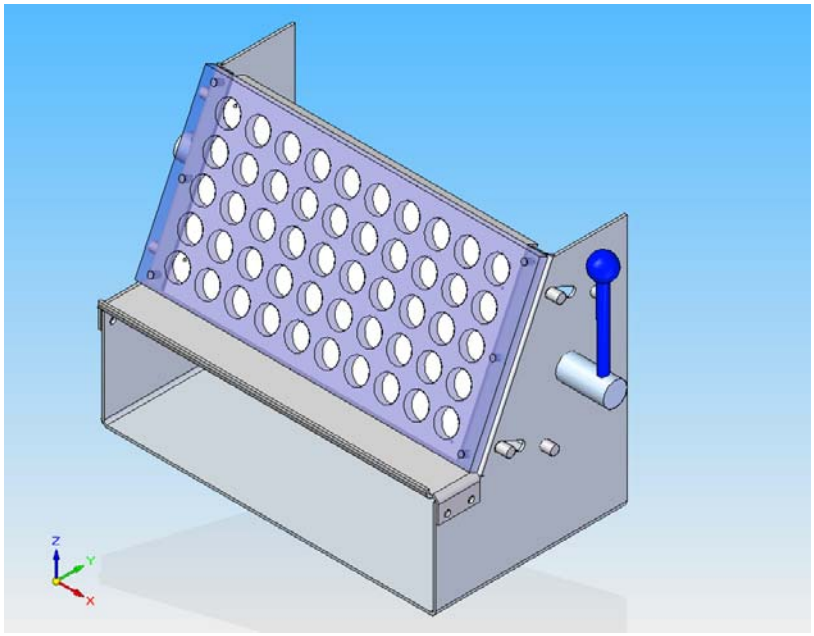

Figure 4.3.3 – Isometric Front

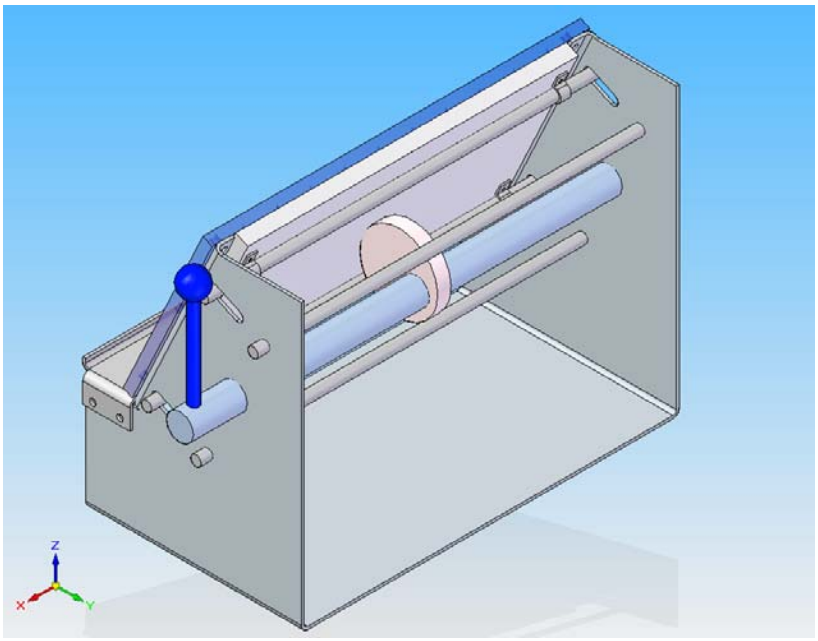

Figure 4.3.4 –Isometric Back

4.3.3 Concept C: Sliding Plate

This concept involves two plates each with 50 one inch holes that begin slightly misaligned. The operator will fill each hole with one part until all are full. Then the operator pulls the bottom plate so that the holes align and the parts drop down into a bagging device. The bottom plate is then moved back into its original position and the process is repeated. The device can be seen as an exploded view in Figure 4.3.5. In reality the bottom plate would never be separated from the top.

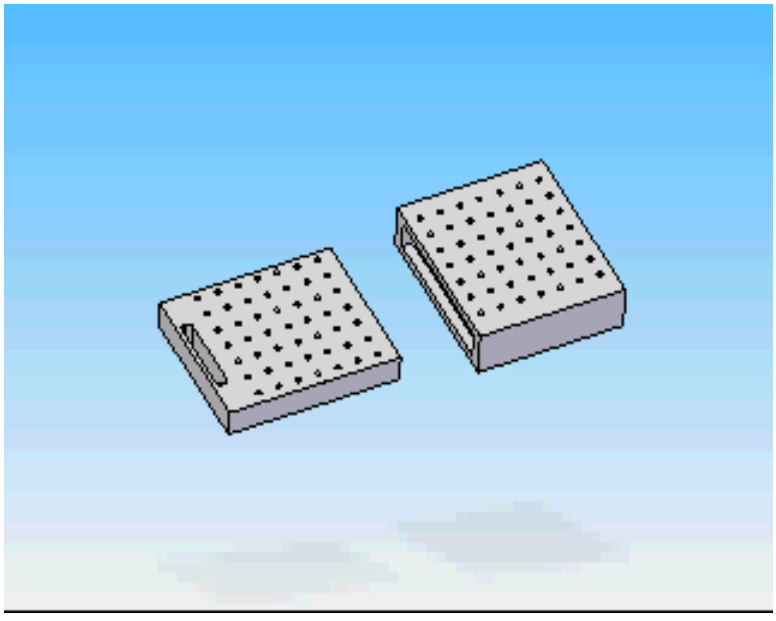

Figure 4.3.5 – Sliding Plate Assembly

4.3.4 Concept D: Rotating Disk

This concept is similar to concept C but instead uses rotation. Two disks with 50 holes each lie on top of each other but the holes are misaligned. The operator fills each hole with one part and turns the top plate when each hole is filled. The bottom plate remains stationary, so when the top holes align with the bottom holes the parts fall through into a bagging device. Figures 4.3.6 and 4.3.7 show this idea.

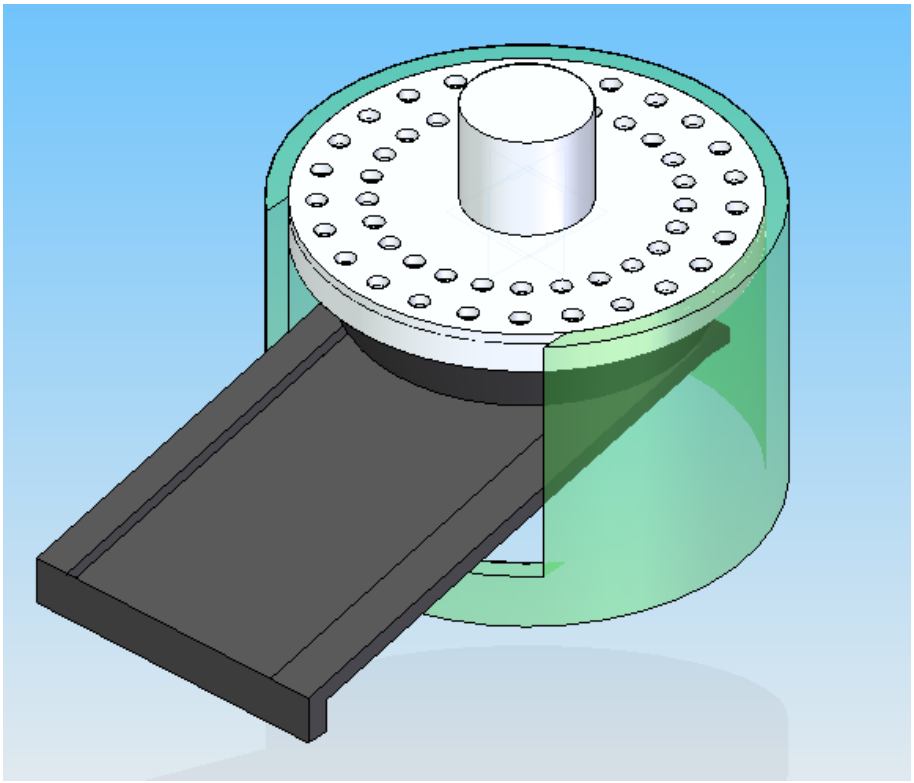

Figure 4.3.6 – Isometric Front

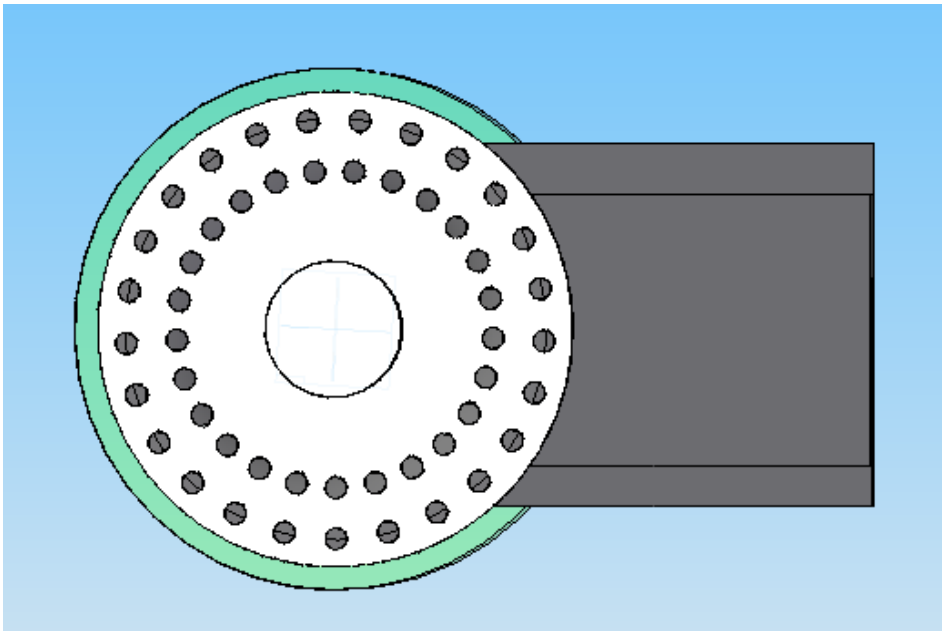

Figure 4.3.7 – Top

4.3.5 Concept E: Roulette Wheel

Our final concept is similar to concept D in that it rotates; however, the part layout is much different. This idea has separate places for the bolts and the nuts and washers. The bolts are laid down in the inner two rings with the place for the nuts and washers in the outer ring. Unlike the other concepts, an entire order can be done in one step. Once the desired number of parts has been placed the operator activates a "trap door" that opens under the parts. The operator then turns the device 360° to allow all the parts to fall through the trap door in a bagging device. This is illustrated in Figures 4.3.8 and 4.3.9.

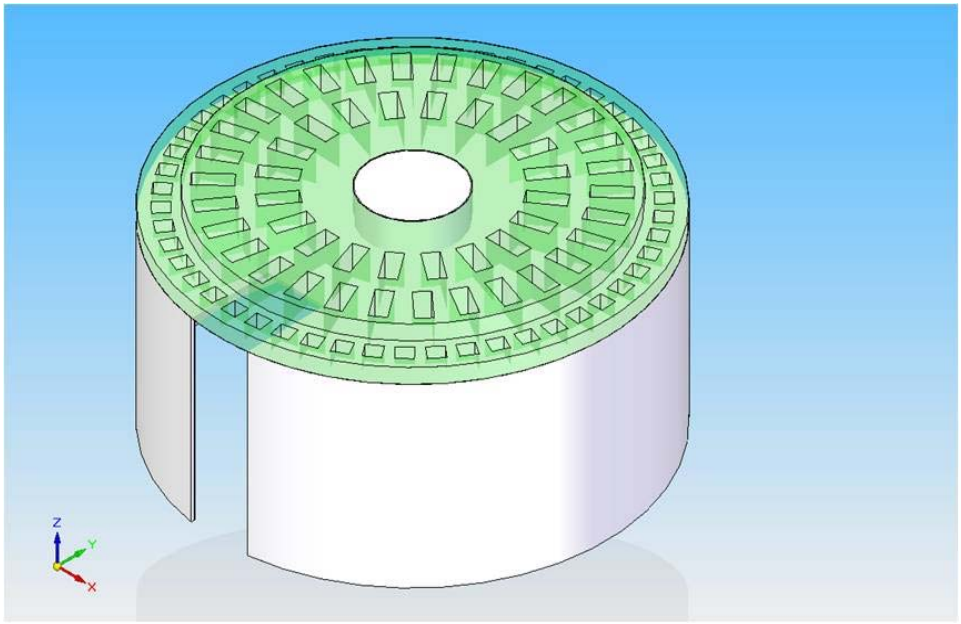

Figure 4.3.8 – Isometric Front

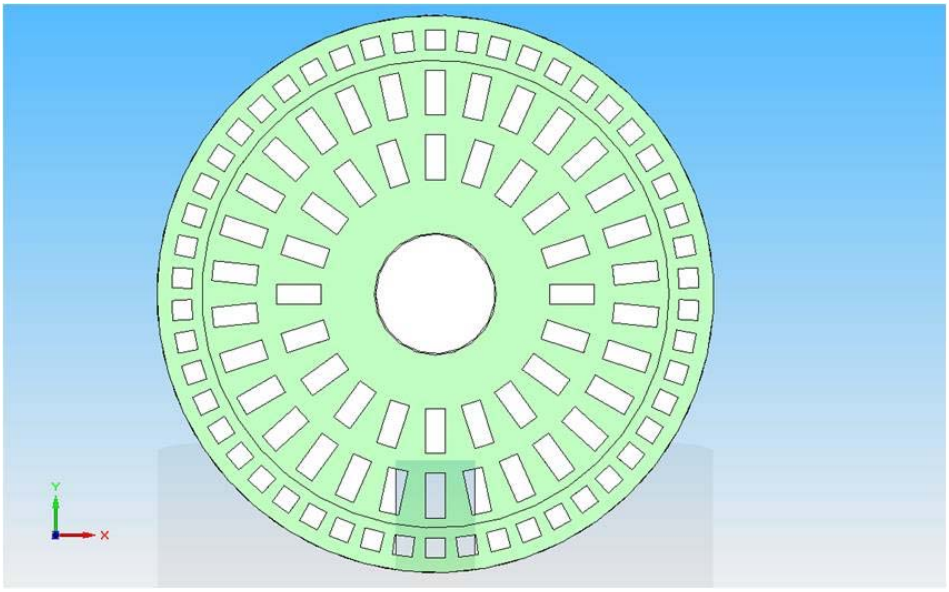

Figure 4.3.9 - Top

4.3.6 Concept F: Grocery Scale

This concept is based off of a grocery scale in a produce department. A completed order is weighed so that the mass of the total product is known. Then the consumer fills one piece at a time on the hanging plate. Once the weight matches the weight of the desired quantity the consumer releases the bottom plate and empties the parts in a bag. The weight will have to be measured with a digital scale because some of the parts are very small and accuracy is paramount. Figure 4.3.10 shows this idea.

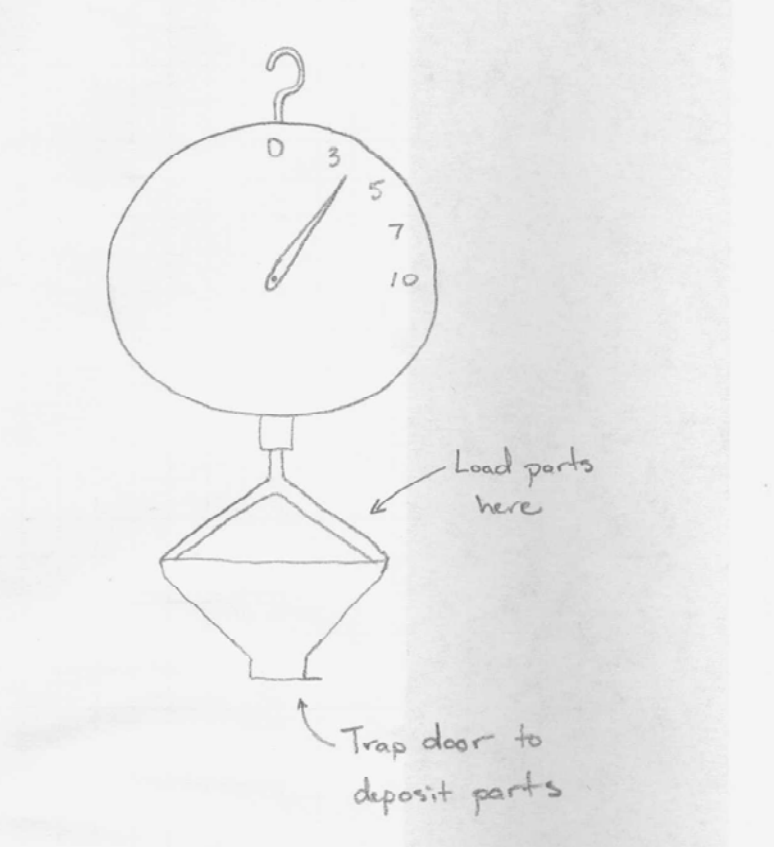

Figure 4.3.10 – Grocery Scale

4.3.7 Concept G: Extending Pegs

This concept works similarly to Concept B; however, instead of the back plate dropping back, pegs push the parts up, out of the holes. The parts then fall down the front of the board through a gathering system and are deposited into a bag. This is displayed in Figure 4.3.11.

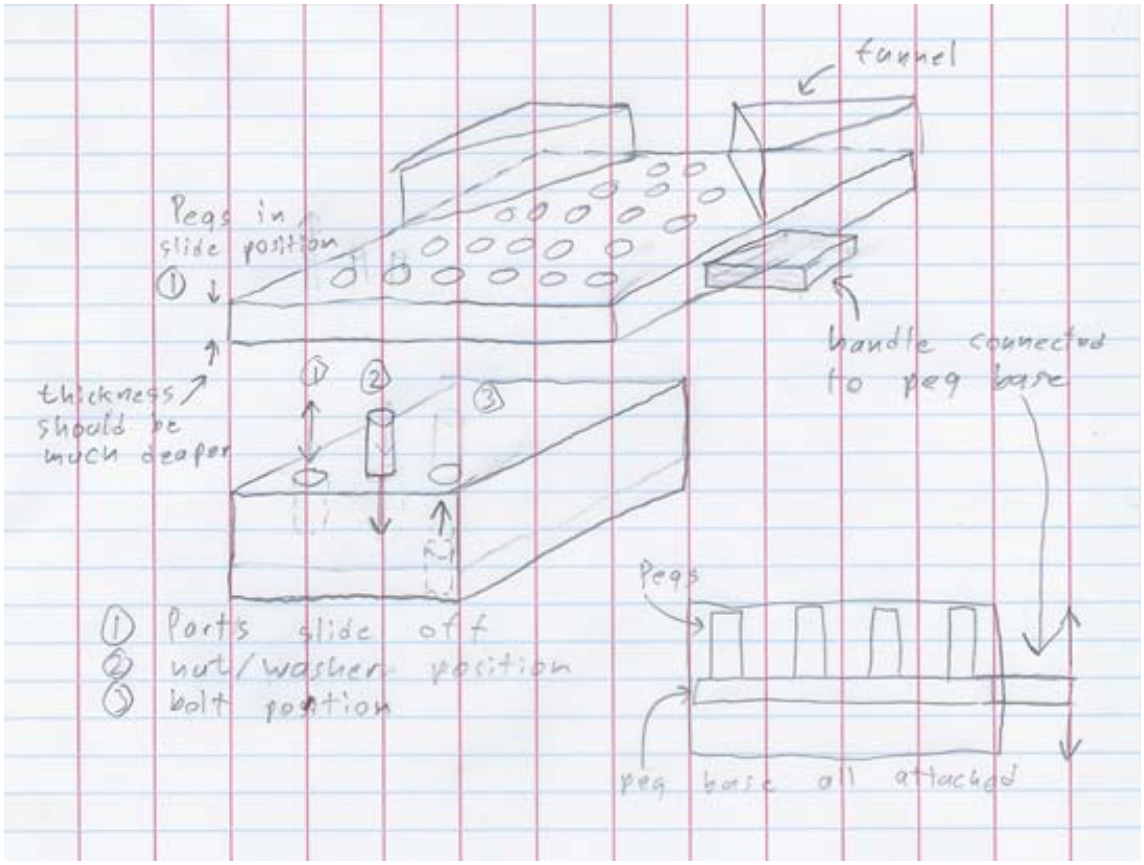

Figure 4.3.11 – Extending Pegs

4.3.8 Bagging Device

A bagging device has not yet been finalized as it would have to be slightly different for each concept. The use of a funnel will be most likely due to its simplicity. However, the details behind securely attaching the bag have not yet been discussed.

5.0 Concept Screening and Evaluation

5.1 Concept Screening

Each device concept submitted was observed by each group member individually. The group then had a meeting to discuss each individual's observations and the devices were then compared to the customer's feedback of the need requirements.

5.1.1 Customer Feedback

Need requirements for the counting device were determined by interviewing Betty Blankenship, the Production Manager for Tri-State Industries. The customer's needs statement is developed in Section 2.2. The concept ideas submitted by each team member must meet specific requirements based on the design criteria given by the customer, listed in Section 3.3.

5.1.2 Screening Process

Three concept screening processes were done in order to narrow down the concept selection. The initial screening process required a list of benchmarking concepts that already existed and a list of concepts submitted by each team member. Some of the benchmarking concepts evaluated in the first screening process can be found in Sections 3.1 and 4.2 as well as some concepts submitted by the group in Section 4.3. The concept need requirements developed by interviewing Betty Blankenship were used in narrowing the concept list down to 7 concepts.

The second screening process evaluated seven concepts that were determined in the first screening process. More time was taken to research and further develop these concepts. However, the concepts were still kept fairly basic in order to save time but still show basic ideas. Models of the seven concepts can be found in Section 4.3. The goal of this screening process was to make a decision on two different concepts and determine the feasibility and effectiveness of the concepts with respect to the customer's needs statement.

5.2 Data and Calculations for Feasibility and Effectiveness Analysis

To determine the feasibility for a 50 part counting device, we first did benchmarking research to see if such machines or devices already exist or have been attempted. This research can be found in Section 3.

Tri-State already uses wooden jigs that can accommodate up to 32 parts. This proved that it is feasible to develop a device to assist in counting parts. Figure 4.1.2 of Section 4 shows the existing wood jigs used by Tri-State. The goal of this project is to further develop and improve these jigs to accommodate 50 parts.

5.3 Concept Development, Scoring and Selection

5.3.1 Concept Development

The goal of concept selection is not to select the best concept but to develop the best concept. After the first screening process, ideas pulled from observing a large list of concepts were taken and applied to a narrow list of 7 total concepts submitted by each group member. Figure 5.3.1 shows the concept development chart used by the group.

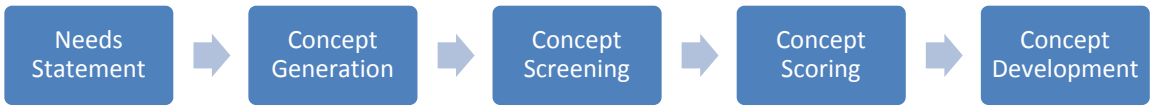

Figure 5.3.1 - "Concept Development Flow Chart"

During the second screening process, the list of 7 concepts were compared and analyzed in a Feasibility chart. Table 5.3.2 is the feasibility chart used in determining which two concepts would be further developed into prototypes. The chart was designed by collaborating with the customer.

	Customer Needs (weighting)	Design Concept				
		A	B	C	D	E
Likelihood of Design to Meet Customer Needs (1-3)	1. Safety (.18)	3	2	3	3	3
	2. Ergonomics (.16)	3	3	2	2	2
	3. Quality Control (.16)	2	3	3	3	3
	4. Productivity (.15)	3	3	3	3	3
	5. Adaptability (.09)	1	3	3	3	3
	6. Cost (.08)	3	1	3	2	1
	7. Size (.05)	3	2	3	2	2
	8. Sustainability (.05)	3	2	3	3	3
	9. Mobility (.03)	3	2	3	2	3
	10. Aesthetics (.03)	1	3	3	3	3
	Total Multiplied by Weightings	2.51	2.38	2.69	2.53	2.48

Table 5.3.2 - "Feasibility Chart"

The weighting of each criterion for the feasibility chart was determined by interviewing Betty Blankenship, the production manager at Tri State Industries. The group met and observed each concept. The likelihood of the design to meet customer needs was given to each concept on the scale of 1 to 3, where 1 is least likely and 3 is most likely. The weight factor of each customer need was explained in Section 2.1. Using the customer's ranking of the needs and the team's evaluation of the needs, the weight factors for each customer need was determined.

Concept C and concept D were determined to be the most likely concepts to meet the customer's needs based on the feasibility chart. These concepts were decided by the group to be further developed. A prototype of each concept will be made next quarter to determine which concept will physically perform better.

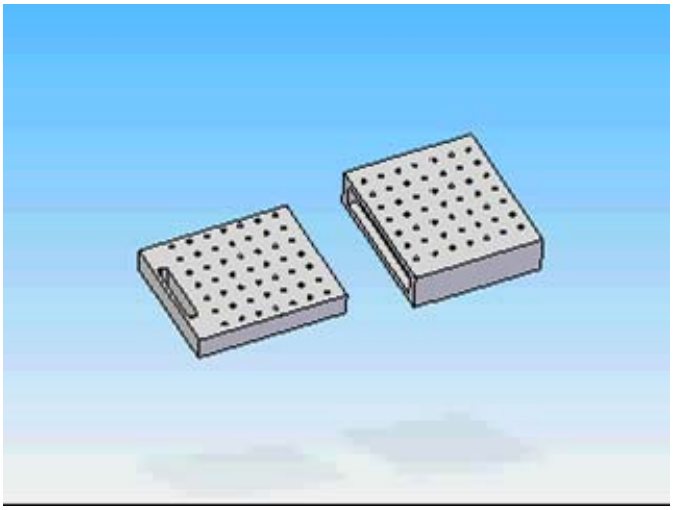

Figure 5.3.1 - "Concept C: 50 Hole Board"

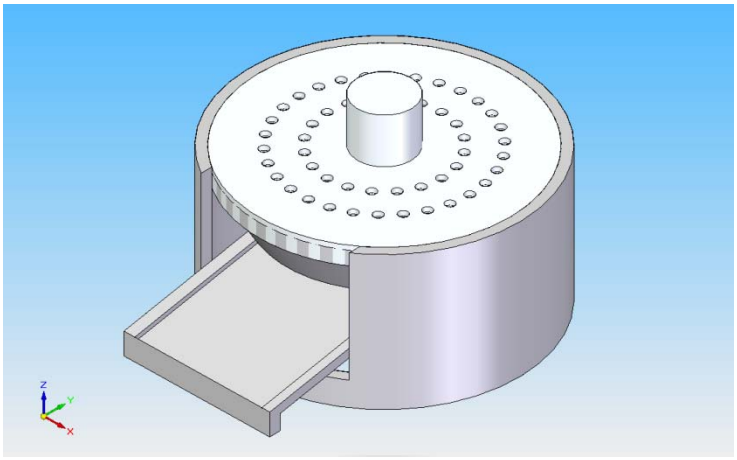

Figure 5.3.2 - "Concept D: 50 Hole Rotating Spinner"

Concept C (Figure 5.3.1) is a 50-hole translating board concept. Concept D (Figure 5.3.2) is a 50-hole rotating disk concept. Both concepts are very broad but are different in how they operate. The other major difference between the two would be the release mechanism that would be activated by the consumer to release the small parts into a bag. A major cause of error in the counting process done by the consumers is the transferring of small parts from the jig to the bag. The bagging process is an important focus to improve the quality control need required by Tri-State.

The release mechanism for Concept C would be to pull or slide the bottom board to release the parts into a funnel or tube to the bag. The board could be moved by hand or by lever. We also believe a board would result in a smaller device because the holes could be placed fairly close together in a row and column pattern. A "Connect Four" game concept was taken into consideration for this idea.

The release mechanism for Concept D would be rotating the upper disk so all the parts fall below into a funnel. It would be fairly difficult to fabricate a disk with 50 holes in it; however, it may function better than a board.

6.0 Final Design Concept

The Final Design Concept chosen for further development is a combination of Concepts B and C. There will be a middle, slider board sandwiched between to stationary boards. When this middle, slider board is pulled laterally, holes in the top and middle boards will align and the small parts hardware will fall through into a funnel that directs them into a bag. This will have the general form:

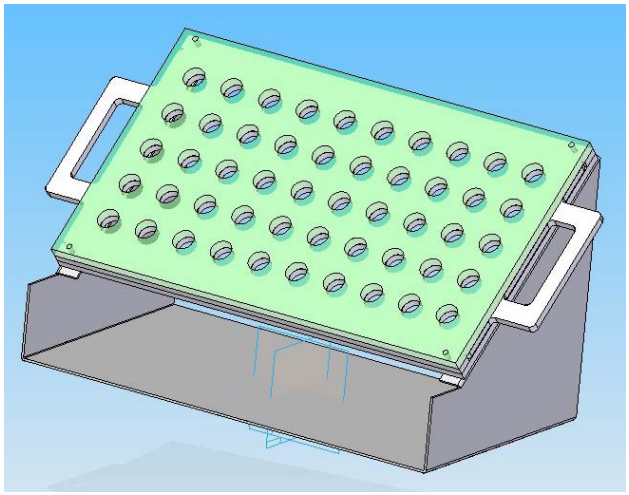

Figure 6.1: Final Concept – Isometric View

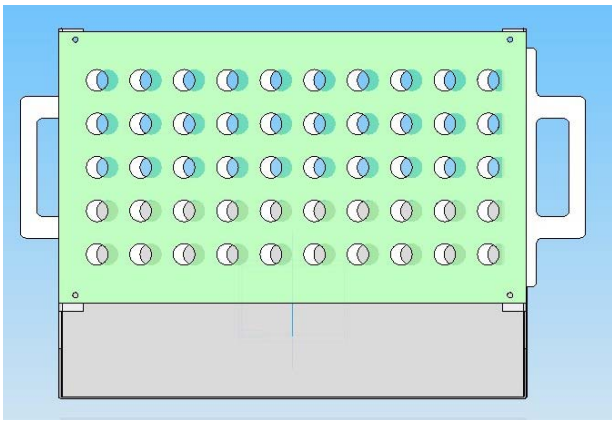

Figure 6.2: Final Concept – Top View

The benefit of a device like this is that there is little effort required by the user. The only input they are required to give is a small lateral force to the left or right (depending on whichever direction is more comfortable for the user) to slide the middle, slider board left or right one inch. A plastic with a low coefficient of friction would do well to further reduce the input force required.

Not shown here is a funnel (not yet designed) that would catch the small parts after they fall through. The funnel may direct the parts to the front, middle, or back of the device. Having the bag in the back of the device to protect it from parts accidently being dropped in the bag. However, having the bag in the front of the device would allow easier access by the user. Further development is required to determine the optimum bag location.

Furthermore, in order to simplify the process and ensure proper operation of the device, either a stopper or automatic return on the middle, slider board is thought to be required. Currently, a

spring system to automatically return the board to its proper starting position (holes closed) is thought to be the best option. If the holes are not closed completely, parts could be dropped into the bag prematurely, causing possible error in the counting process.

7.0 Prototype Design, Development and Testing

7.1 FMEA

To ensure that our design was the best possible to solution to the problem the HandiCats performed a FMEA on the design to see if there were any areas that would need to be redesigned before construction. Figure 7.1 illustrates the major concerns we have for the performance of our device. These issues would render the device unusable, and possibly inflict harm to the user or damage to the environment.

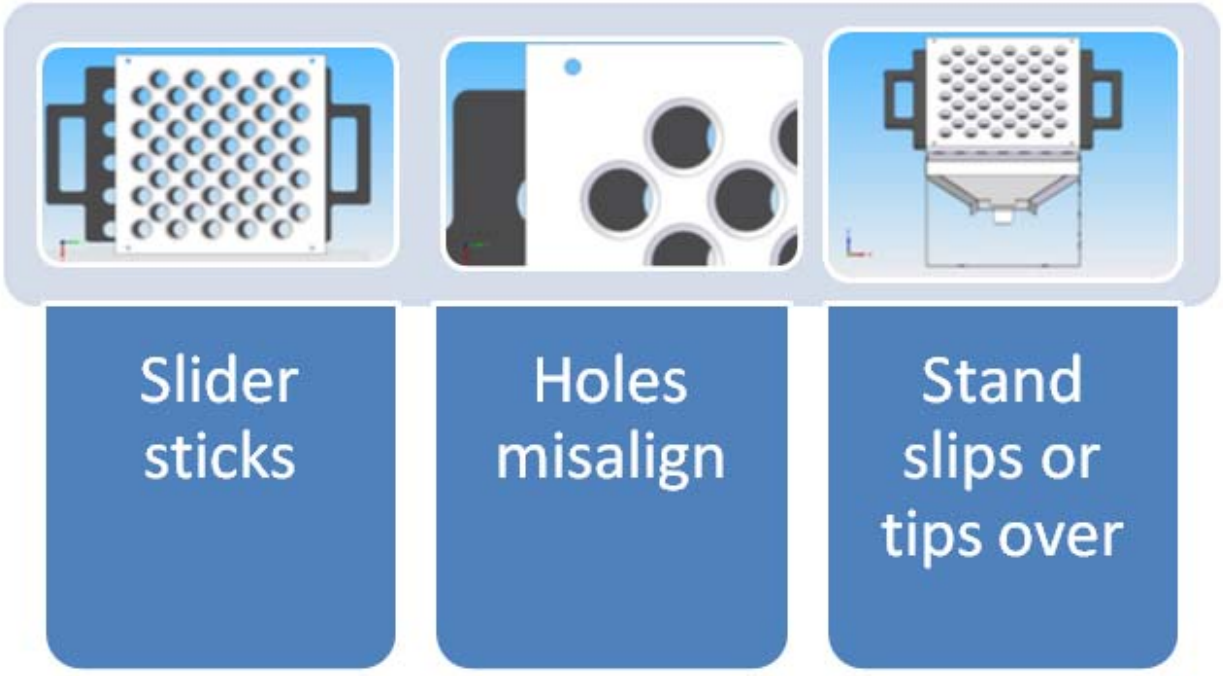

Figure 7.1.1 – Major Functionality Concerns

If the slider board were to become stuck or difficult to move the device could not be used. This could be caused by too much friction between the slider and the top board. A possible solution for this issue is to use a material with a low coefficient of friction like we have with UHMW. If this is not enough we may have to investigate lubricants. The boards could also stick if the magnets are too powerful. We must test the magnets before we permanently install them in the board assembly.

If the holes misalign the device could not be used because this would introduce too much possibility for error to the system. One possible cause of this would be if a part being counted were to not fall through completely and get stuck. Another possibility could be that the magnets do not work properly and align the boards incorrectly. Or the user will not bring the magnets close enough together to cause them to attract. In order for improvements to be made we assigned each failure mode a rating from 1 to 10, with one being the best and ten being the worst, in three separate categories: probability of occurrence, severity of failure, and the probability of detecting the failure.

Table 7.1.1: Failure Ratings

	Occurrence	Severity	Detection	Total
Slider Sticks	4	6	9	216
Holes misalign	7	4	9	252
Stand slips or tips over	6	3	7	126

By doing this process we can identify the aspects of the design that need to be addressed by which category has the highest total. This total was calculated by multiplying all the factor values together. The acceptable threshold was 150; however the ideal would be less than 100. Only the stability of the stand is in the acceptable range at this point with both the stinking slider and the misaligning of holes being well outside acceptable. The biggest factor in this FMEA is the lack of failure being detected. These failures will happen quickly and will probably not give signs ahead of time that they will happen. From this we see that the greatest threat to the functionality of the device is the holes not aligning.

To substantiate our claim that failure by tipping or sliding is unlikely to occur we tested the model using finite element analysis. The results of this test are explained in section 7.2. However these are not the only ways that the device can fail. These are simply the most likely to occur in the normal operation of the device.

7.2 Design Analysis

In order to verify the design before the prototype was constructed, the team performed Finite Element Analysis. This analysis focused on two separate failure modes of the design: the failure of the 14 gauge steel stand (bending) due to a horizontal force and the failure of the UHMW Polyethylene sliding board due to a vertical force. The first failure mode of the stand bending was deemed possible due to the lack of side support, such as cross members would give. For the analysis of this failure mode, the model of the stand was imported into ALGOR. The model was constrained at various nodes on the horizontal surface constituting the base of the stand. This method was selected to produce accurate results if the stand were to bend. Forces of 25 lbs each

were then applied perpendicularly to the sides of the stand as is seen in Figure 7.2.1 below. There are red arrows that point to the right show where the force is being applied and in what direction. The red triangles at the bottom show where part is constrained. It can be seen how the part is divided up into a mesh in this figure as well. These forces simulate a person leaning partial weight on the device.

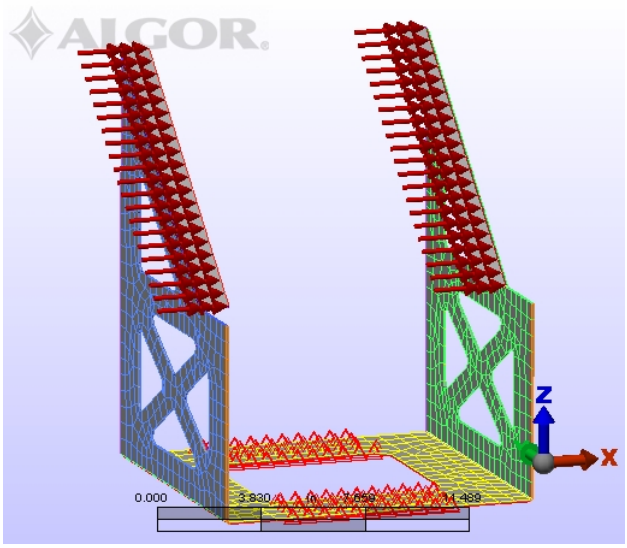

Figure 7.2.1: Constraints and Forces Applied to Stand Model

The analysis was run at various mesh sizes in order to ensure convergence of the results. Upon convergence, it was found that the maximum Von Mises stress in the model was 37,140.2 psi, while the maximum strain was 0.0016 in/in. It is important to note that the highest stresses did not occur at the 90° bends, where they were expected to occur. Instead, the maximum stresses developed in spots on the flat vertical surface, much higher than the bends. This can be seen in Figure 7.2.2 below.

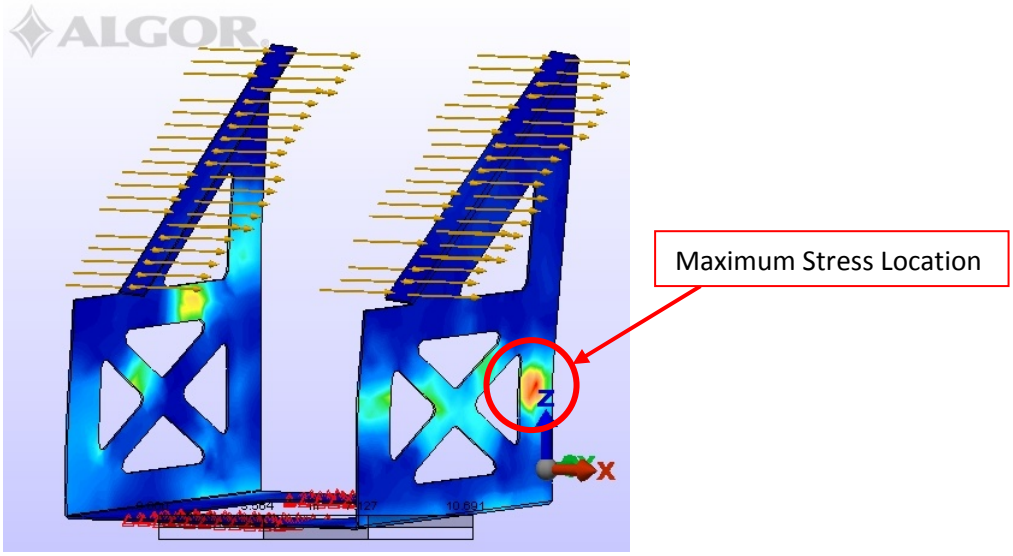

Figure 7.2.2: Stress Analysis on Stand

Based on this finding, as well as the maximum stress being below the yield stress of 53,000 psi, the stand alone has a factor of safety of 1.43 for this failure mode.

In order to further verify the design, a model with all of the sheet metal parts was tested. This analysis was performed using plate elements and refinement points for better accuracy and simulation time. The results of this analysis showed that the highest incurred stress on the model was 8,772 psi with a maximum deflection of 0.02 in. Again, the maximum stress was much lower than the yield stress of 53,000 psi yielding a factor of safety of 6.04 for the fully assembled device. Based on these analyses and the certainty of the parameters and results a factor of safety of 6 should be sufficient for this failure mode.

The second failure mode of the sliding board fracturing was deemed possible due to the lack of support when fully extended. Analysis was run in ALGOR to determine the maximum stress of both a 25 lb and 50 lb load on the sliding board. For a 25 lb load, the sliding board was found to have a maximum stress of approximately 1,700 psi at the location indicated in Figure 7.2.1 below. This would give a factor of safety of 1.82 for a 25 lb load.

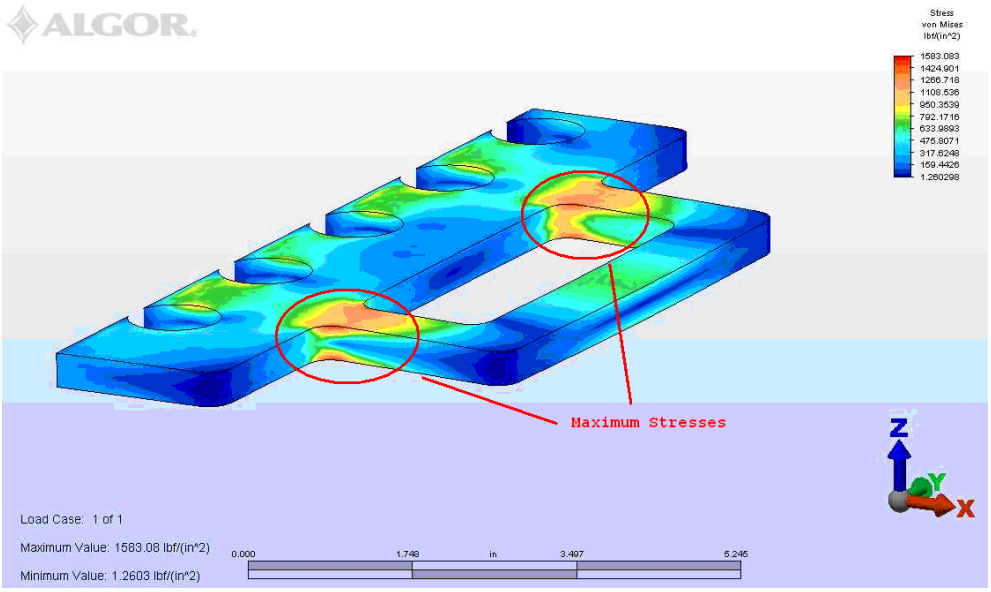

Figure 7.2.3: Von Mises Stress - 0.1 in mesh, 25 lb force, cut fully fixed

For a 50 lb load, the sliding board had maximum stresses in the same areas as indicated in Figure 7.2.1; however, the stresses for this load indicate that the sliding board would fail at this load. Upon physical testing, it was determined that this was, in fact, incorrect. Upon be subjected to a load much greater than 50 lbs, the material simply bent; there was no fracture of the material. The testers were able to bend a linear piece of the material into a circular shape without failure. It is believed that the reason for the discrepancy between physical testing and the finite element analysis was a result approximation of the material properties in ALGOR. Because UHMW

Polyethylene was not in the material library of ALGOR, its Modulus of Elasticity, Poisson's Ratio, and Tensile Strength were added in order to simulate the material. Further details of the analysis are shown in Appendix B.

7.3 Mock-ups, Experiments, Testing

In addition to the simulations run in ALGOR, several physical tests were performed to validate the prototype. The first of these tests involved determining if the device would bend, deflect, tip over, or move when a force is applied to the sliding board. The second of these tests involved a production and quality analysis.

7.3.1 Sliding Board Analysis

In order to analyze that the device will not bend, deflect, tip over, or move when a force is applied to the sliding board, a test was created to determine the force necessary to move both the sliding board and the entire device. For the first part of the test, a force gauge was attached to the sliding board. The force required to move the sliding board between closed and open position was tested for two different scenarios: with the magnets imbedded in the middle and bottom boards and without the magnets. The maximum force required to move the sliding board was found to be 1.75 lbs with the magnets and 0.75 lbs without the magnets. For the second part of the test, the force gauge was attached to the stand of the device. The force required to move the entire device was determined to be 3.75 lbs. Because the force required to move the device was more than twice the force required to move the slider, there is low risk of the device tipping over or moving when the force is applied. The force required to move the sliding board is also much lower than the force required to bend or deflect the sliding board (according to the FEA results in the previous section). In addition, the force of 1.75 lbs is approximately equal to three medium oranges, which should prove acceptable for the employees at Tri-State to exert. A detailed report of the experiment is included in Appendix C.

7.3.2 Production & Quality Analysis

In order to test the production and quality of the device, the supervisors at Tri-State were asked to perform a two week trial of the device with two different employees. The two employees were both timed and checked for accuracy. The first employee, a higher functioning employee named Corrinna, was able to reduce her time 50-73% and maintain zero errors for the entire two week trial. The second employee, a lower functioning employee named Ben, was originally not able to perform the task. With the device, he was able to complete the task and maintain zero errors for the entire two week trial. Both employees increased production while maintaining the quality of the work.

7.4 Prototype Construction

During the construction of the prototype a variety of methods were used. The fabrication of the stand and other metal parts was contracted out to a plasma cutter to ensure that the dimensions were held. The plasma cutter also added perforations to the metal to aid in bending the stand and to relieve some of the stresses in the steel. The plastic parts were made in house using the CNC milling machine in the Mechanical Engineering Design Laboratory. We decided to use the CNC mill over the manual mill because the placement of the holes needed to be exact or there will be overlap which would result in the holes misaligning. With the help of Randy we developed a CNC program that involved drilling each hole with a ½" drill bit and then milling out the rest of the hole with an endmill.

We encountered some difficulties in using the CNC because we were pushing the limits of the travel of the tooling. Also, because the piece was large, 12" by 12", and made of plastic we could not just support the piece around the edges. If we had the piece would have bowed in the middle under the force of the drill. This would have most likely have resulted in slanted holes and at the worst it could have cracked the piece. We had to improvise using scraps of plastic and superglue to create supports that would run down the middle of the part and hold the piece securely to the milling table.

Another important part of our design was the development of plugs. These plugs would be used to "fill" unwanted holes so that different quantities could be counted without installing a new board. These plugs were done of the CNC lathe so that an ergonomic profile could be place on them and they would all be the same. Our first design had to be redone after we tested the prototype plug. It was too tall and therefore too top heavy and would fall out of the hole. This was in part because it could not extend more than ½" below the surface of the top board or it would keep the slider board from moving. Also, we had too much clearance for the plug to fit in the hole. We shortened the plug and made it fit tighter and now it works perfectly.

8.0 Design Refinement for Production

Design Refinements:

- Cut out part of rear tab to access board assembly nuts
- Catch tray to catch parts that were dropped
- Shortening the length of the bolts so parts would not get caught in the funnel
- Changing the dimension and tolerance for the slider board height to allow it to slide with enough clearance without slotting any holes.
- Changed manufacturing processes to reduce time
- Remove rear support part

We noted the issues we had while assembling the device. From the assembly process we found a lot of issues that needed changed to ease the manufacturing. We also tried out the device ourselves. One of the ways we refined our device was by sending the prototype to the customer

to get feedback. We had the customer write down any problems and recommendations they had for it. Overall, they were satisfied with the design with some minor changes. We did a cost analysis of the prototype to look at possibly reducing the cost for the final design.

8.1 Final Design Development and Validation

All the validation is described in section 7 for the prototype validation. We did not do any additional validation for the final design changes. The changes were small and did not require any FEA or physical tests.

The impact of our DFMA and design changes made it easier and quicker to manufacture and assemble. These changes also made it function better. We made changes to the manufacturing process that would reduce the labor time reducing the overall cost.

One of the manufacturing processes that were changed was the way the 50 holes were milled out of the plastic. For the prototype we drilled out small holes with a drill bit and milled the rest of the material out to reach the desired tolerance. In the final design the initial holes drilled out by a drill bit will be larger. This will reduce the milling time by about an hour for each part reducing the overall cost while staying in the desired tolerance.

The initial prototype did not allow clearance in one of the planes for the sliding part. We did not notice this until it was assembled. For the prototype, we had to slot the holes of the spacer parts and push them out so that the middle board would have the clearance needed. For the final design we reduced the height of the middle board and tightened the tolerance of that dimension to ensure enough clearance for the moving part without slotting any holes. The rear support piece was also interfering with the sliding. This part was not needed for the final design, so it was replaced by two washers to keep the same needed stack up. This also reduced the weight and overall cost.

Parts were getting caught by the bolts holding the funnel into place. This was noted by the customer during their trial period. On the prototype we cut the bolts. On the final design we are reducing the length of all the sheet metal bolts so we still have only two types of bolts overall. There is one type of bolt for the plastic parts and one type for the sheet metal parts.

While assembling the device we found it very difficult to get a hold of the nuts for the board assembly. The support tab in the back was blocking access, so we had to grind out a piece of it. In the final design this is now part of the initial sheet metal cutout. This is shown in Figure 8.1.1.

Figure 8.1.1: Assembly access improvement

While trying it out ourselves we noticed that it was easy to drop parts onto the floor if the hole was missed. In the final design we included a catch tray on the front of the device that will catch parts before they fall onto the floor. This is shown in figure 8.1.2.

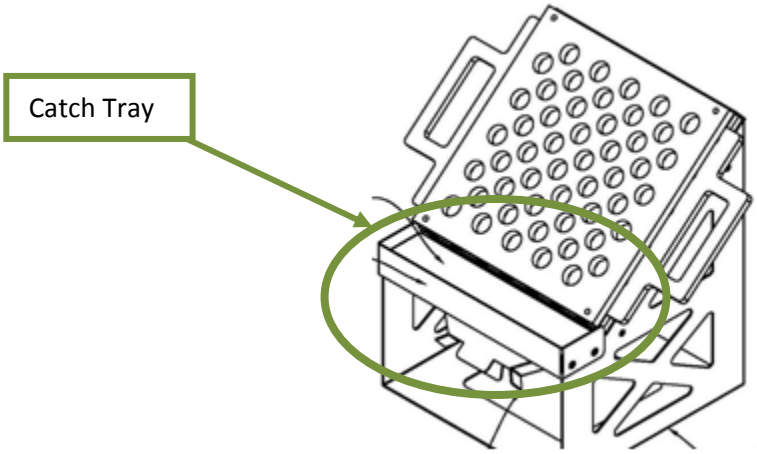

Figure 8.1.2: Catch tray improvement

We did not waste any material for the prototype and we did not make any changes to the material for the final design. Therefore there are no savings in material for the final design.

9.0 Final Design for Production

9.1 Design Description and Operation

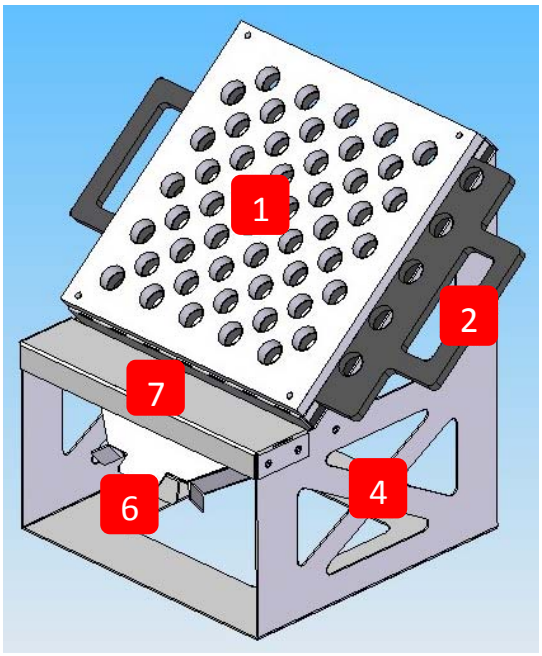

Figure 9.1.1: Final Design – Front Isometric View

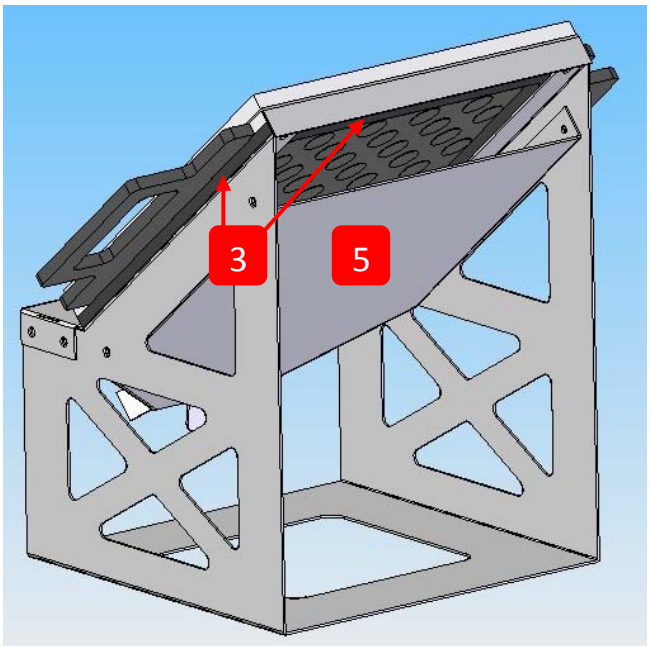

Figure 9.1.2: Final Design – Rear Isometric View

The finished product has the following features:

Table 9.1.1: Final Design Features

	Name	Material	Description
1	Top Board	UHMW-PE*	Has 50, one-inch holes to place parts into during counting, with four additional holes in each corner for bolts for securing to stand
2	Middle Board or Slider	UHMW-PE-SD**	Has holes similar to, but opposite of, Top Board. Two handles on either side provide a place to grip during operation. Houses one magnet.
3	Bottom Board	UHMW-PE-SD**	Simple board with large hole cutout in the middle to allow parts to fall through. Also provides support/smooth surface for Slider. Houses one magnet.
4	Stand	16 Gauge Steel	Holds board assembly up from the table and at an ergonomic angle
5	Funnel	16 Gauge Steel	Catches and directs parts toward bag
6	Funnel Opening	16 Gauge Steel	Directs parts into bag
7	Catch Tray	16 Gauge Steel	Catches any dropped parts during counting

*Ultra-High Molecular Weight – Polyethylene

**Ultra-High Molecular Weight – Polyethylene – Static Dissipative

It is important to note that the magnets in the slider and bottom board are located such that in the neutral or closed position they align correctly.

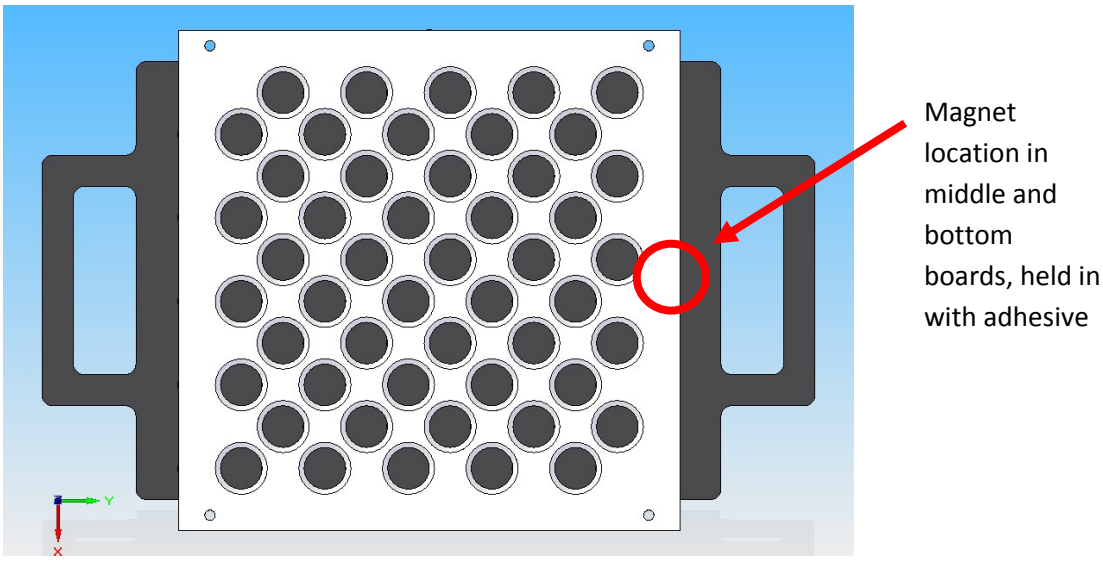

Figure 9.1.3: Board Assembly – Closed Position

Considering an order of 50 parts (50 nuts, 50 bolts, and 50 washers) this device was intended to work as such:

- **Step 1**: Place bag on clip. Slide one lip of a zip-lock bag through the clip on the funnel opening. Stretch the remainder of the bag around the funnel opening.
- **Step 2**: One part of one part type is loaded into each of the 50 holes of the top board while the slider is in its neutral or closed position (see Figure 9.1.3). In other words, only one part is loaded into each hole and during one phase of the operation only one part type (bolts, nuts, or washers) are counted.
- **Step 3**: Slide the middle board laterally to the left or right (about 1.5 pounds of pull are required to overcome the magnets). The holes in the middle and top boards will align and the parts will drop through to the funnel. The parts then slide down the funnel, out the funnel opening, and into the awaiting bag. Return the middle board to its neutral position. The magnets will catch and hold the middle board in perfect alignment for the next run.
- **Step 4**: Repeat this process two more times with the two remaining part types. Once all three part types have been counted and collected in the bag, the bag can be removed by simply pulling down and out from the bag clip.

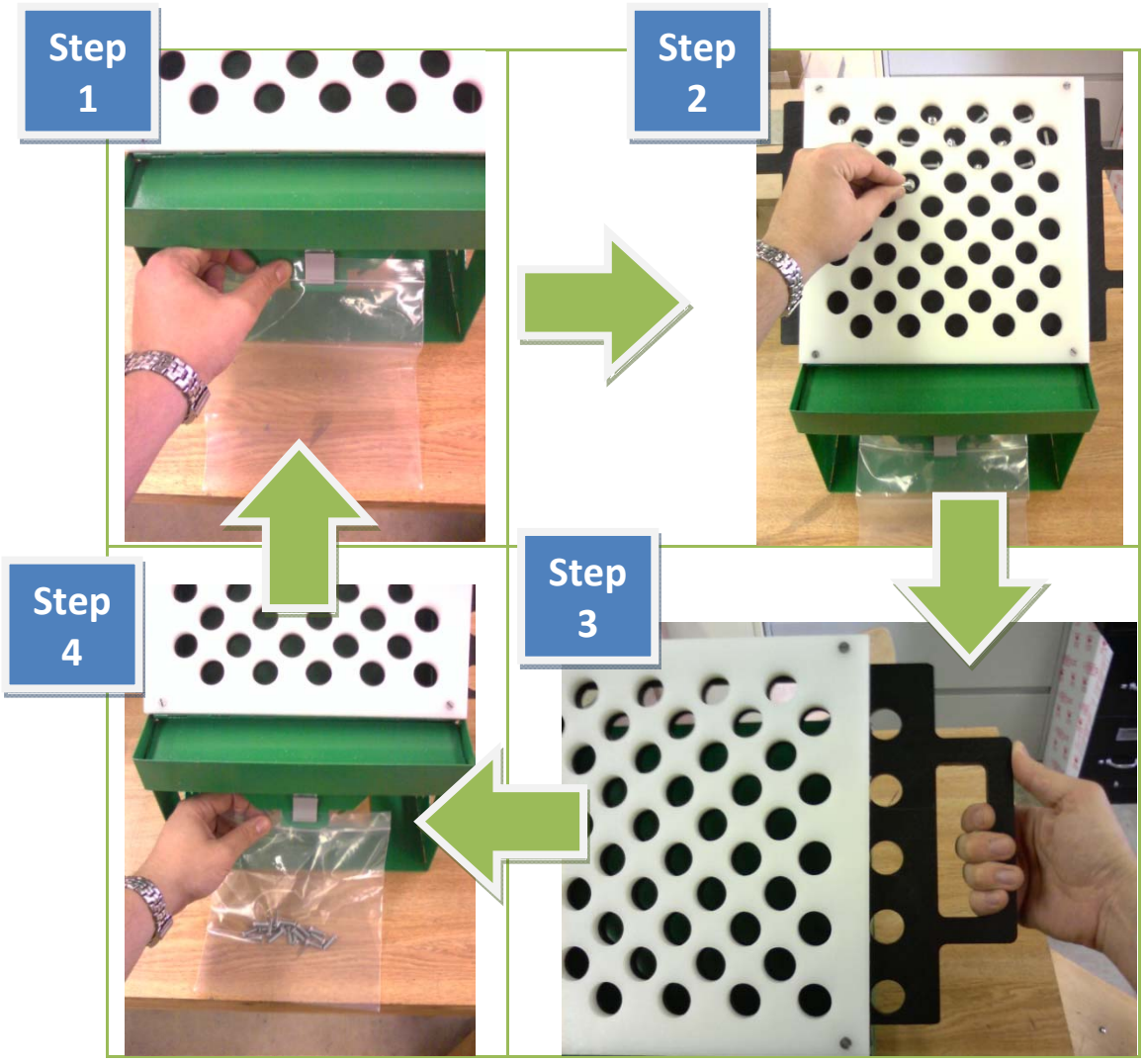

Figure 9.1.4: Small Parts Counting and Bagging Process Procedure

9.2 How is it Manufactured and Assembled, and What Does it Cost?

The manufacturing of this device is very simple; it can be summarized as follows (see Figure 9.2.1):

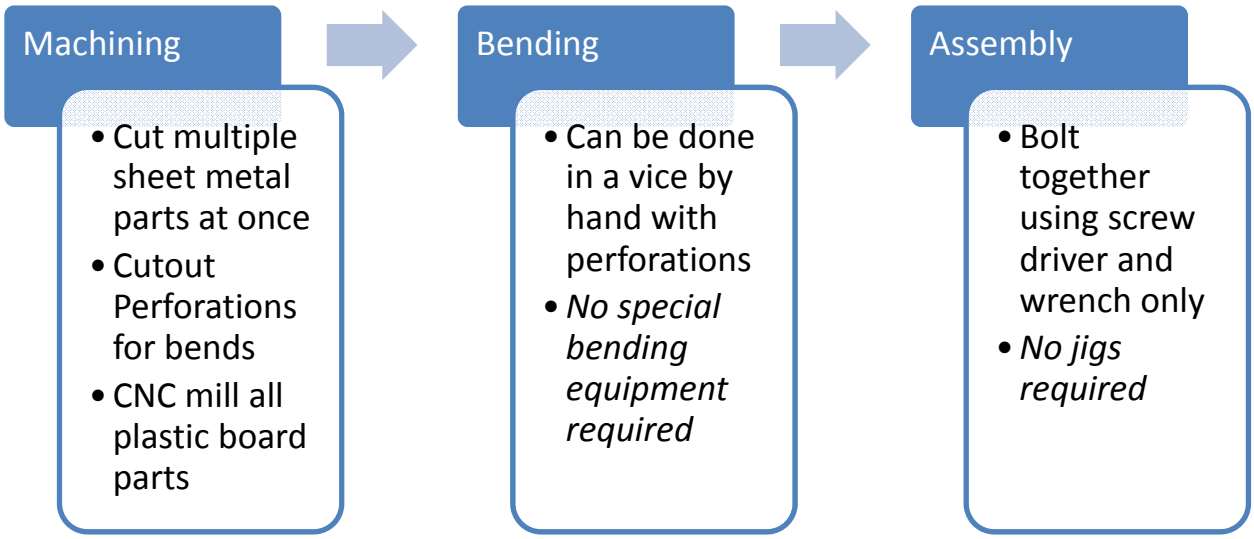
Machining
• Cut multiple sheet metal parts at once
• Cutout Perforations for bends
• CNC mill all plastic board parts
Bending
• Can be done in a vice by hand with perforations
• *No special bending equipment required*
Assembly
• Bolt together using screw driver and wrench only
• *No jigs required*

Figure 9.2.1: Summary of Manufacturing Processes

The metal sheets would be cut out preferably but a laser cutter into the following shape (see Figure 9.2.2).

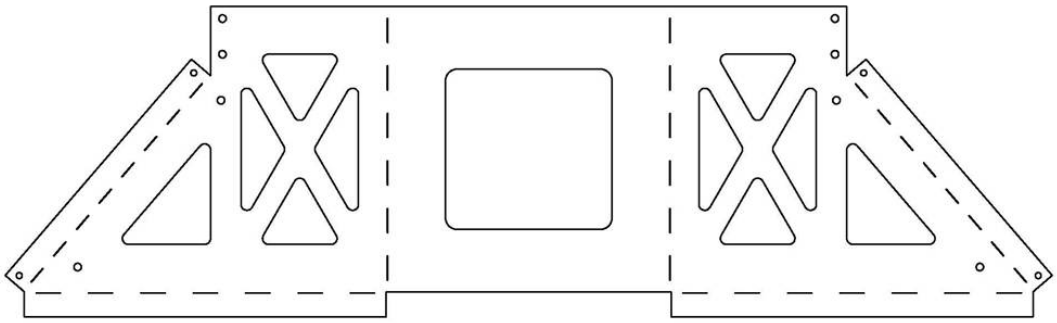

Figure 9.2.2: Metal Stand Cutout including Perforations

Assembling this device is also very simple. Once the metal stand (Figure 9.2.2) is bent into shape and the plastic boards are cut into shape, they only require nuts and bolts to be secured. This hardware also doesn't require any special torque loads when tightening. Therefore, the only tools required is a flat head screw driver and an appropriately sized wrench. The plastic boards will receive four bolts, the funnel will receive four bolts, and the shield (located at the base of the plastic parts, used to catch any parts accidently dropped during the loading process) will receive four bolts as well. All the holes to receive bolts are predrilled. Adhesive is also used is some locations, such as the stoppers on either side of the slider board and the foam pads on the handles, if pads are desired. The stoppers are extra pieces of UHMW cut to fit on the slider

handle to restrict undesired motion. Please refer to the User's Manual for additional information on safety (See Appendix D).

The approximate cost of such a production plan would be:

Table 9.2.1: Production Cost Rundown

Materials Cost		
Part	**Description**	**Cost**
Top Plastic Board	UHMW-PE*	$15
Middle Plastic Board	UHMW-PE-SD**	$30
Bottom Plastic Board	UHMW-PE-SD**	$15
Metal Stand	16 Gauge Steel	$100
Hardware	Nuts, bolts, adhesive, bag clip	$10
	Total	$170
Operations		
Basic Operations	100% Overhead, 50% Equipment Factors at $12/hour	$60
Special Operations	Added 25% Tolerance Factor $20/hour	$60
	Total	$120
	TOTAL	$290

* Ultra-High Molecular Weight Polyethylene

** Ultra-High Molecular Weight Polyethylene Static Dissipative

For the operations section, the labor cost was calculated as:

1. Basic Operations
    a. 2 hours for stand production and overall assembly
        i. $2\ hours\ \times \frac{\$12}{hour} \times [1 + 1 + 0.5] \cong \$60$
2. Special Operations (CNC Milling)
    a. 30 min for top board
    b. 30 min for middle board
    c. 5 min for bottom board
        i. $65\ min \times \frac{1\ hour}{60\ min} \times \frac{\$20}{hour} \times [1 + 1 + 0.5 + 0.25] \cong \$60$

If the customer would also choose to have plastic plugs made to restrict the number of holes available for counting, the cost estimate is as follows:

1. Materials
    a. 5 ft. of UHMW-PE
        i. $5\ ft \times \frac{\$2.37}{ft} \cong \$12$
2. Special Operations
    a. 60 min for 35 plugs
        i. $60\ min \times \frac{1\ hour}{60\ min} \times \frac{\$20}{hour} \times [1 + 1 + 0.5 + 0.25] \cong \$55$

3. Total Cost
    a. 35 plugs would cost an additional $12 + $55 = $67
    b. Final cost of product with plugs is $357

9.2.1 Design Drawings, Parts List and Bill of Materials

The design drawings further detail the product. They show manufacturing tolerances, exploded views of more detailed sections, as well as parts lists. These drawings are given in Appendix E.
In order to professionally and efficiently draft all parts of the SPCaBD a drawing border was developed specifically for Team HandiCats. The drawing border contains important information pertaining to each part's tolerances and features. Figure 9.2.3 shows the information block within the drawing border.

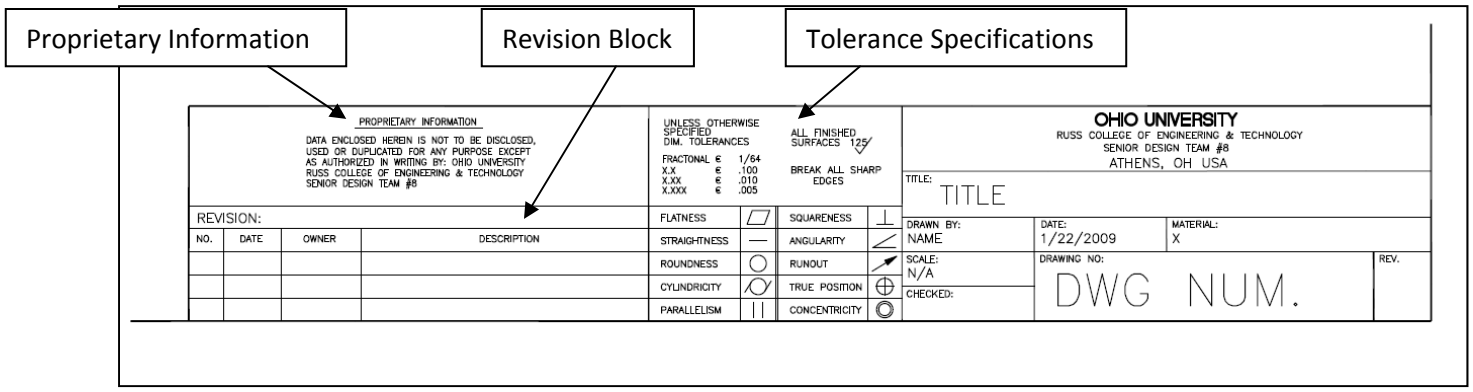

Figure 9.2.3: "Drawing Border Information Block"

The information block of the drawing border states that unless specified in the drawing, specific tolerances are to be followed based on the number of decimal places present in each dimension. Figure 9.2.4 is a close-up of the Tolerance Specification block.

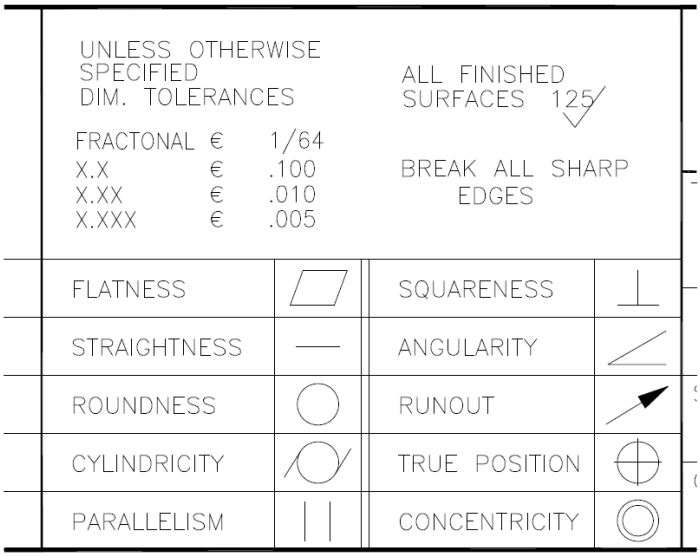

Figure 9.2.4: "Tolerance Specification Block"

10.0 Conclusions

The goals/objectives of this project, as stated in Section 1.0.4, were concluded as follows:

1. Assist people with disabilities in the workplace *Accomplished*
   The employees of Tri-States Industries were very excited to use our product. It improved their focus, desire to do the work, and ability to achieve the appropriate accuracy. Furthermore, their supervisors are also very pleased with the results after using our device.

2. Learn how to both manage and lead a team *Accomplished*
   Each team member took control of certain deliverables within the project scope at some point(s) within the academic year. This enabled each of us to learn how to manage the work as well as lead.

3. Effectively use project management tools *Accomplished*
   Management tools such as the project scheduler in Microsoft were used effectively to plan out project deliverables.

4. Perform background research and benchmarking *Accomplished*
   Background research was done in the beginning of the project to determine benchmarks that already exist. Further research was done as the project progressed and the device's functionality was put to the test.

5. Work with customers to fulfill a need *Accomplished*

   As stated before, Tri-Industries is very pleased with the device developed for their workers. Communication was held since the beginning of the project and continuous feedback was exchanged between both parties.

6. Design and build a functioning prototype *Accomplished*

   The prototype is fully functional and accomplishes many of its design specifications laid out in previous sections (see below for more detail). The prototype is ready for production and implementation outside of its primary customer.

7. Effectively document and present pertinent information *Accomplished*

   Through the year, project presentations have been given that effectively communicated to the other engineering students our design concepts, their development and implementation. Furthermore, engineering notebooks have been documented with all the details of the project as they unfold.

8. Submit a completed application and design report to NISH *Accomplished*

   A design report was submitted to NISH. Although NISH saw improvements that could have been made, the project as it applies to the NISH standards, was an overall success. Moreover, a patent will be filed for this design for further development for similar companies around the United States.

9. Remain within budget and on schedule *Accomplished*

   The budget referred to is the overall budget given to Team HandiCats at the beginning of the project, which amounted to $300. Since all the labor was done by Team HandiCats, the only costs relative to this project were material costs. Given the simplicity of the device, the prototype stayed just under budget. We were also able to stay within the limits of our project schedule the entire year.

After delivering the product to the customer for testing for about two weeks, we have determined the following characteristics of the device in relation to our initial customer specifications:

Table 10.1: Product Outcomes in Relation to Specifications

	Customer Specification	**Product Achievements**	**Comments**
Size	≥4 stations to be used per 3’ x 8’ table	~8 stations could be used per 3’ x 8’ table (36” x 96”)	Slider board is 18.5” wide with 1” of travel in either direction. Given some clearance, the required station area for one device is about 22”.
Accuracy	<1% error	0% error	Goal achieved.

Simplicity and Ease of Operation	1. Usual workers can operate with minor training 2. Open job to new workers previously unable to do work	1. Employees understood basic operation within first trials 2. New employees able to effectively use device	Goal achieved. 1. Employees understood operation and enjoyed doing it. (Accuracy <10%) 2. Lower functioning employees successfully used device (Accuracy 10-50%)
Life Expectancy	5 years before any maintenance inspection	5 years before any maintenance inspection	The boards and stand are expected to achieve a much longer lifetime. Stoppers or bolts loosening is possible but requires only simple checks.
Easy Maintenance	<1 year maintenance experience needed	<1 year maintenance experience needed	The metal and plastic boards will hold up to normal wear and tear. More adhesive or hand tightening of bolts is extent of required maintenance.
Adaptability	1) Metal or Plastic 2) ≤1" bolt 3) ≤50 parts	1) Any material 2) ≤1" bolt length 3) ≤50 parts	Goal achieved.
Production Rate	Target Spec: 15.6 parts/min Design Criteria: 50 parts/min	20-33 parts/min	Goal achieved.
Weight	<10lbs	17 lbs	*Goal not achieved.* But supervisors are safe to carry 17 lbs and it provides enough friction with table to be stable.
Safety	No sharp corners or edges, pinch points, quick movements, or sticking within any moving parts	All corners/edges are rounded, pinch points are limited, large quick movements avoided, some sticking present	Goal achieved. Magnets provide some "sticking" effect, but are easily overcome and intended for safe operation. Stoppers restrict too much motion otherwise.
Ergonomics	Workers must be comfortable during normal operation	Workers are comfortable	Goal achieved. One or two employees had to stand up to use this device; however, they do not operate the device for extended periods of time.
Aesthetics	Increase workers' focus	Increased workers' focus	Goal achieved. Device makes work like a game. Effectively keeps their attention.
Cost	<$100 per device	$290 - device only $357 - device with plugs	*Goal not achieved.* $100 per device was approximate. Tri-State is still willing to raise money for more devices.

Two goals were not achieved by this product: weight and price per device. However, after careful review, the product is a success.

First, the weight of device was an approximate value set before any design concepts were considered. When approached about a preferable weight, the Tri-State supervisors had no immediate input. The weight of 10 pounds was then suggested by Team HandiCats as a target specification to aim toward. Unexpectedly, the weight of 17 pounds is actually much safer because of the added friction it causes between the bottom of the device and the table. This added friction keeps the device from sliding on the table during normal operation. According to the supervisors, this device will only be moved occasionally by the supervisors themselves and 17 pounds is well within their physical capabilities. Therefore, although the target specification was not met, the weight of the device is not a failure, but actually a success – in unexpected ways as well.

Second, the price of the device was also an approximate value set before any design concepts were considered. When approached about a preferable price, the Tri-State supervisors suggested less than $100. While the final production cost reaches $290 without the additional plugs, Tri-State remains extremely interested in our product. Therefore, the expected result of this price jump is that Tri-State will simply buy a lower quantity of the devices then they were originally planning. This does not mean that fewer employees will be able to use this device. Tri-State will simply need to space out the work done with these devices. Although not a good strategy for other facilities, Tri-State Industries is not run totally by volume output. As long as the orders are filled in time, which they have in sufficient quantities, they succeed. Furthermore, the plugs are simply a delighter in the overall product concept; they are an optional feature depending on the needs of the individual customer.

Given these product outcomes, the device is ready to be released to the customer, Tri-State Industries. CNC programs have been written for manufacturing the plastic boards and CNC programs can be attained through the initial metal fabricator. Detailed part drawings are already made (see Appendix E). Before the device is fully production ready, more detailed production plans with actual fabricators would need to be set. Also, if enough of such devices are requested based on market review, the per unit production cost may decrease to a more widely accepted value, allowing the product to be more production ready.

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Appendices

Appendix A: Additional Figures

Table A.1: AHP Pair Wise Comparison Chart

	Safety	Ergonomics	Quality Control	Productivity	Adaptability	Cost	Mobility	Sustainability	Size	Aesthetics	Total	Weighting
Safety	1.00	1.11	1.11	1.20	2.00	2.22	3.33	3.33	5.88	5.88	27.06	**0.18**
Ergonomics	0.90	1.00	1.00	1.06	1.79	2.00	3.23	3.23	5.26	5.26	24.73	**0.16**
Quality Control	0.90	1.00	1.00	1.06	1.79	2.00	3.23	3.23	5.26	5.26	24.73	**0.16**
Productivity	0.83	0.94	0.94	1.00	1.67	1.89	3.00	3.00	5.00	5.00	23.27	**0.15**
Adaptability	0.50	0.56	0.56	0.60	1.00	1.12	1.79	1.79	3.00	3.00	13.92	**0.09**
Cost	0.45	0.50	0.50	0.53	0.89	1.00	1.59	1.59	2.63	2.63	12.31	**0.08**
Mobility	0.30	0.31	0.31	0.33	0.56	0.63	1.00	1.00	1.67	1.67	7.78	**0.05**
Sustainability	0.30	0.31	0.31	0.33	0.56	0.63	1.00	1.00	1.67	1.67	7.78	**0.05**
Size	0.17	0.19	0.19	0.20	0.33	0.38	0.60	0.60	1.00	1.00	4.66	**0.03**
Aesthetics	0.17	0.19	0.19	0.20	0.33	0.38	0.60	0.60	1.00	1.00	4.66	**0.03**

Appendix B: Analytical Structural Analysis

For the analysis of this failure mode, the model of the sliding board was cut to represent its fully extended mode. This was seen in Figure 7.2.3 in Section 7.2. The model was then imported into ALGOR. The analysis was run using two different sets of constraints. The first set (used for the initial 0.3 in, 0.2 in, and 0.1 in meshes without mid-side nodes) consisted of the cut surface being fully fixed. The second set (used for the 0.2 in mesh with mid-side nodes, as well as a 0.2 in mesh without mid-side nodes) consisted of the board being allowed to slide. The cut surface was constrained in the Z and X directions, while the back surface was constrained in the Z and Y directions. A load was placed in the negative Z direction on the handle to simulate the user pushing downward on it. The load was varied between approximately 25 lb and 50 lb for each case.

After running all several analyses, it was determined that the part will likely fail with a load of approximately 50 lb. Just before this load, the maximum deflection is approximately 0.84 in. A sample of the stress results was seen in Figure 7.2.3.

The complete results of the analyses can be seen in Table 1 below. Scenario 1 is without mid-side nodes, and the cut is fully fixed, Scenario 2 is without mid-side nodes, and the cut is not fully fixed, and Scenario 3 is with mid-side nodes, and the cut is not fully fixed. The convergence of the analyses was tested by calculating the percent differences of the maximum Von Mises stress and the maximum displacement for the 0.3 in, 0.2 in, and 0.1 in meshes of Scenario 1. The results of these calculations can be seen in Table 2 below. Although the maximum Von Mises stress was determined to reach the tensile strength with a load of approximately 50 lb, the load is unlikely to reach this amount in “normal operation.” This is due to the fact that the user will be seated, while reaching upward to slide the middle board. However, it is possible to reach this load if the user leans on the board while not seated.

Table B.1: FEA Analysis Results

Scenario	Mesh Size (in)	Force (lb)	Nodes	DOF	Max Von Mises (psi)	Displacement (in)
1	0.3	25.027	1,165	3,495	932.45	0.18
		50.025			1,863.82	0.37
	0.2	25.025	2,298	6,894	1,463.80	0.40
		50.05			2,927.60	0.80
	0.1	25.08	11,824	35,472	1,583.08	0.42
		50.16			3,166.17	0.84
2	0.2	25.025	2,093	6,279	1,583.08	0.42
		50.05			3,166.17	0.84
3	0.2	25.168	7,637	22,911	1,695.53	0.41
		50.16			3,379.21	0.82

Table B.2: Convergence Justification using Scenario 1 Data

Case	Load (lb)	% Difference	
		Max Stress	Displacement
0.3 to 0.2	~25	44.35	75.86
	~50	44.40	73.50
0.2 to 0.1	~25	7.83	4.88
	~50	7.83	4.88

Appendix C: Physical Testing

C.1 Introduction to Need

There are a small number of situations that affect the small part counting and bagging device (SPCaBD) that need to be tested in order to ensure proper functionality of the counting and bagging process. The force applied to the handle of the sliding board must be analyzed in order to determine if the device will bend, deflect, tip over, or move when the force is applied.

C.2 Background Information

When a force is applied to an object many different results can occur. The object can move, bend, break, or even tip. For this experiment, the tipping force, friction force, and moving force will be analyzed. Theoretical force values can be determined using the equations below, but the experimental force values will be determined using a force gage. As shown in Figure C.1 below a tension force will be applied to the force gage that will be attached to the device. The applied force will be continually increasing until the device slides on the table, the device tips over or until the sliding board moves as desired. If either of the first two scenarios occurs, the device will

need to be redesigned to acquire the desired result. If the device slides on the table, the friction coefficient between the table and device will need to be increased possibly by adding a different material to the bottom of the device. If the device tips, some supports may need to be added to the sides to ensure that the device stays upright.

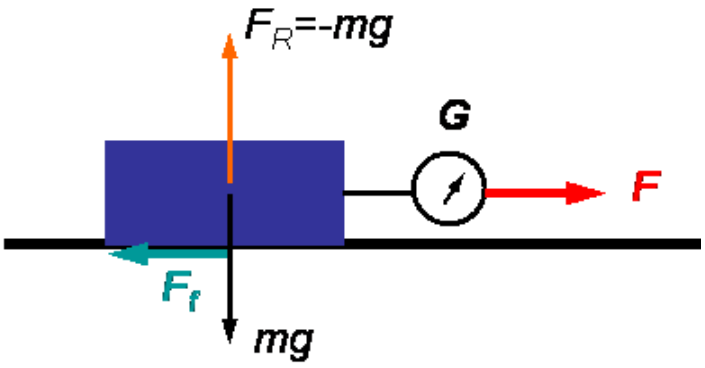


Figure C.1: Diagram of Experiment [Goc, 2009]

C.3 Specific Aims

The purpose of this experiment is to determine the assembly's ease of use. Depending on the force required to pull or slide the middle plate, how easy is the system to operate? This pull force will have to overcome any friction present between the plastic boards as well as the magnetic force holding the plates in proper alignment. This "proper" alignment refers to the holes in the middle plate being off-center to the holes in the upper plate; this way, the holes do not line up and the parts can rest within the upper holes while lying on the middle plate.

The plastic chosen is Ultra-High Molecular Weight Polyethylene (UHMW). This plastic purposefully has a low coefficient of friction similar to Teflon. It is widely used in machinery as friction pads to allow quick, easy movements. It also has very good abrasion resistance to reduce wear and prolong its lifetime. For these reasons, it is expected that the friction between the boards is extremely low ($\mu \approx 0.12$). Therefore, one of the main objectives of the experiment will be to determine the pull force needed to overcome the magnets.

Rare earth magnets were selected for their high strength-to-size ratio. The magnets are Ultra-High-Pull Neodymium-Iron-Boron magnets. They are rated at 10 times the strength of regular Alnico magnets; approximately 1.7 lbs maximum pull. However, that rated pull force would be directed out normal to the magnet's face. It is expected that a force perpendicular to its face (or a sliding force) will be less severe. Therefore, the experiment will determine that sliding force needed to separate the magnets. Once separated by even a quarter of an inch, the magnets do not affect each other, so further sliding of the middle plate will be unaffected by the magnets. This portion of the sliding operation will be purely under the effects of friction. As discussed previously, this is expected to be low. Consequently, it is hypothesized that a pull force of about

one to two pounds will be all that's required to initially slide the middle plate. After that, the board should slide freely with little to no effort.

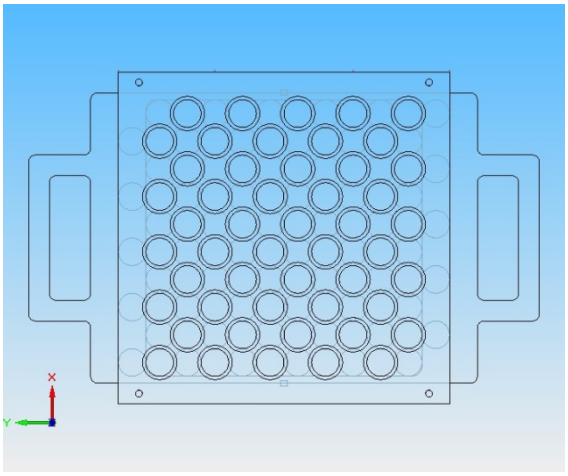


Figure C.2: Full View of Jig

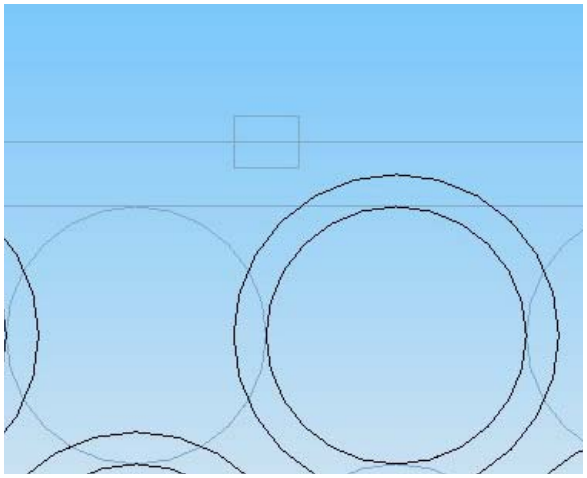


Figure C.3: Close-up of Magnet Slots

C.4 Significance

The two main areas of the experiment at hand involve the field of magnets and the field of coefficients of friction. Both areas were researched in order to determine the relevance of past experiments.

There has been a great deal of research done in the field of magnets; however, most of this research involves knowing the magnetic field strength of the magnets being used. This strength is then used to calculate the force of attraction between the magnets. This research can be helpful as background information; however, the approximate force of attraction between the two magnets being used in the system is already known. Therefore, the magnetic field strength does not need to be used to recalculate it.

The second area of interest is that of the coefficient of friction both between the middle board and top and bottom boards, as well as between the stand and the table. The research on the coefficient of friction between the middle board and the top and bottom boards proved to be quite useful. The material being used for all three boards is Ultra High Molecular Weight Polyethylene (UHMW), which was found to have a coefficient of friction against itself of 0.12 (*More About Static Dissipative. . .*, 2009). Information regarding the coefficient of friction between the stand (steel) and the table (laminated wood) was not as readily available. It was determined that the coefficient of friction between wood and steel ranges between 0.2 and 0.6 (*Carbide Depot*, 2009); however, this is a rather broad range and does not specify laminated wood, which is likely to incur less friction.

While the force of attraction between the magnets and the coefficient of friction between the boards are known, there have been no documented experiments found in our research where both

of these factors have been taken into account. Additionally, little research has been done into the effects of using a steel stand (such as with this system) on a laminated wood surface. For these reasons, the experiment at hand is quite important. The workers (also known as Consumers by Tri-State Industries) have limited mobility, which suggests that the force required to slide the middle board between the top and bottom boards should be minimized, without allowing the stand to slip on the table.

Both the safety and well-being of the consumers are of the utmost importance in this project. The system should be designed such that the force required by the consumer is minimized, and that the system will not slide on the table upon which it is set up. The results of this experiment will impact whether the system will be attached to the table and how so. If the system is found to slide only slightly, a solution such as rubber feet could be employed. However, if the system is found to slide more than slightly, clamps could be purchased in order to attach the stand to the table.

C.5 Experimental Procedure

A force Gauge will be needed for this experiment. The force gauge will be attached to the middle handle of the sliding middle plate. Refer to figure 2.1 for the apparatus diagram. Data acquisition from the computer can be used to record the force vs. time.

1. The SPCaBD will be placed on a wooden table without being locked down.
2. The force gauge will be attached to the handle.
3. The force gauge will be pulled by hand without holding the SPCaBD with the other hand or securing it in any way.
4. When it is pulled one of three things may happen. The SPCaBD may tip over, slide on the table, or the middle plate will slide out to perform the desired function.
    a. If the SPCaBD tips over we will record the peak force required to tip the stand from that point and try to reduce the sliding force.
    b. If the stand slides on the table before the plate slides we will record the peak force which is the static friction force between the metal stand and the wood table. We will also record the constant force vs. time during the sliding time which is the kinetic friction force. From this information we can also calculate the friction coefficients of the stand and the wooden table based on the stand weight.
    c. We will then clamp the SPCaBD to the table and pull out the plate and record the peak force. This force is the friction force between the plates in addition to the force of the magnets.
    d. If the SPCaBD performs as desired the middle plate will slide and we will perform the test as described in c. without clamping it to a table. We will also perform the tests described in a. and b. by attaching the force gauge to another

part of the SPCaBD to see how close we are to the friction force and tipping moment.

5. We may need to adjust the clearances of the plates and magnetic force to get a comfortable sliding force. We should set a quantitative goal based on the strength of the users, the friction forces, and the tipping moment and try to meet that goal to make it easy to use and prevent the need of a clamp.

6. We will repeat each data recording five times and take the average to get an accurate value.

C.6 Results

The results from our experiment can be seen below in Table C.1. The data for the slider pulled without magnets is recorded as RNM and LNM ("right, no magnets" and "left, no magnets" respectively). For the slider pulled with the magnets installed the abbreviations RM and LM were used. Graphs made from the data all resemble the graphs below. Figure C.3 below shows the results of sliding the entire device alone on the table. The maximum force needed came to be about 3.75 pounds. The maximum force to pull the slider without the magnets was approximately 0.75 pounds. The maximum pull required to move the slider and overcome the magnets was approximately 1.75 pounds.

C.7 Uncertainty Analysis

Due to the simplicity of the prototype and experimental procedure, error was kept to a minimum. However, some error was present in the data acquisition device used to measure the required input force. The Vernier Force Probe has two settings where it can measure a maximum force of ±10N or ±50N. When measuring the force required to pull the middle board across the test probe was set at ±10N; however, when testing the force required to slide the entire device across the table, the ±50N setting was used. According to the test probe's specification booklet, its resolution at the ±10N setting is ±0.01N and when set at ±50N its resolution is ±0.05N. Therefore, the test probe was 0.57% accurate on the sliding force for the middle board and 1.3% accurate on the sliding force for the entire device.

C.8 Conclusions

From the results above we feel confident that the user will be very comfortable using this device. Pulling with a force of 1.75 pounds is equivalent to lifting 3 medium sized oranges or a fifth of a gallon of milk, which is reasonable to ask. Also, this force will not be constantly held but instead only be applied for a few seconds during each operation. Furthermore, the workers will only use the device sparingly, taking multiple breaks throughout the course of a day. There is also not going to be an issue with the entire device moving laterally across the table due to the force needed to move the slider. The force needed to slide the entire device was almost twice that to move the slider. However, as a safety precaution we will put a friction pad on the bottom of the device to increase its resistance to motion. It's interesting to note that the magnets were rated at

1.7 pounds maximum pull by McMaster-Carr. Therefore, if after field testing it's decided that the 1.75 pounds is too much for the employees, replacement magnets can be found.

Table C.1: Table of Results

	Average (lbs)	Peak (lbs)
LNM	0.46	0.64
LNM	0.46	0.66
LNM	0.47	0.73
LM*	0.85	1.45
LM*	0.76	1.57
LM*	0.84	1.73
RNM	0.48	0.59
RNM	0.43	0.57
RNM	0.50	0.69
RM*	0.86	1.58
RM*	0.84	1.55
RM*	0.79	1.59
LNM AVG	0.46	0.68
LM AVG	0.82	1.58
RNM AVG	0.47	0.62
RM AVG	0.83	1.57
NM AVG	0.47	0.65
M AVG	0.82	1.58

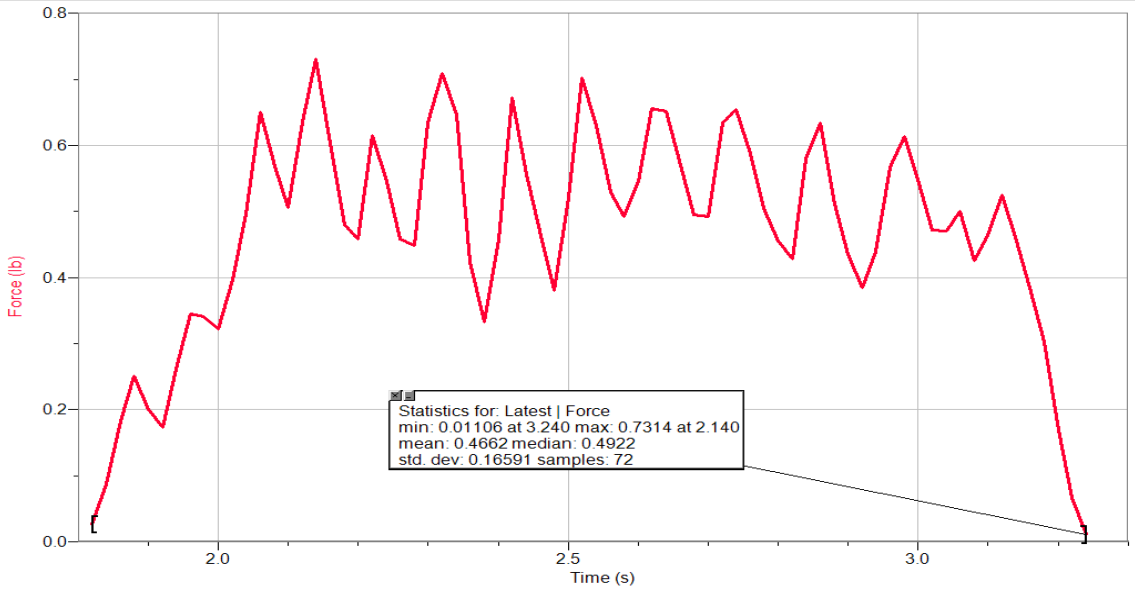


Figure C.1: No Magnets Force Data

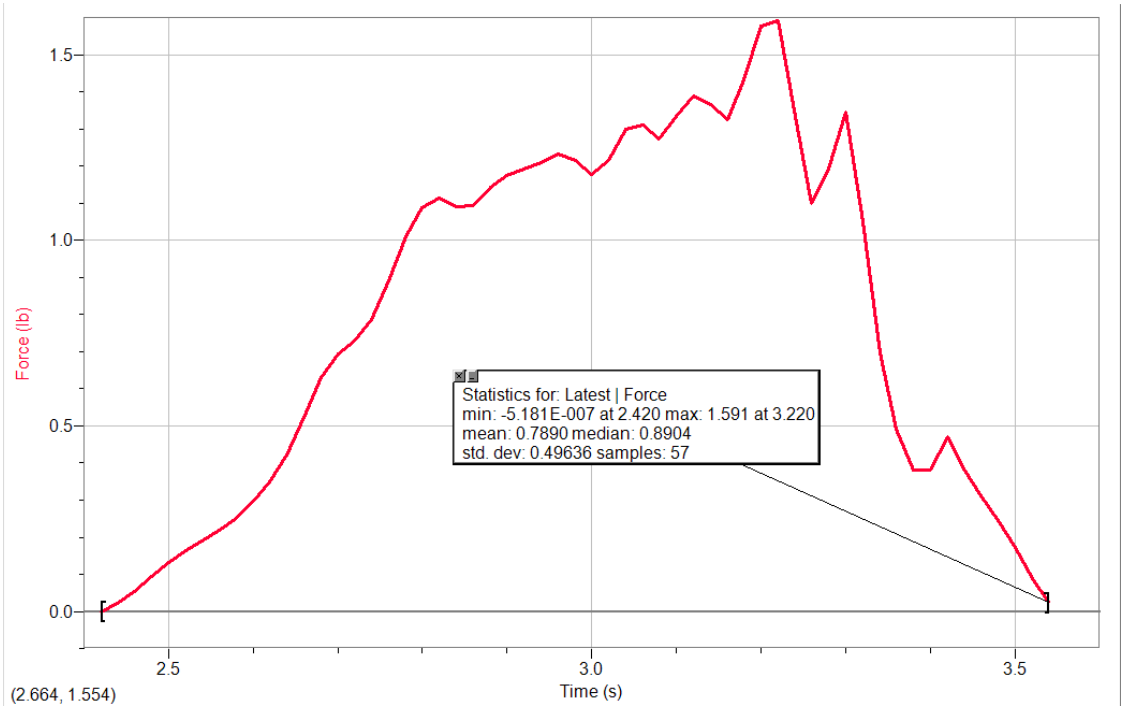


Figure C.2: Magnets Force Data

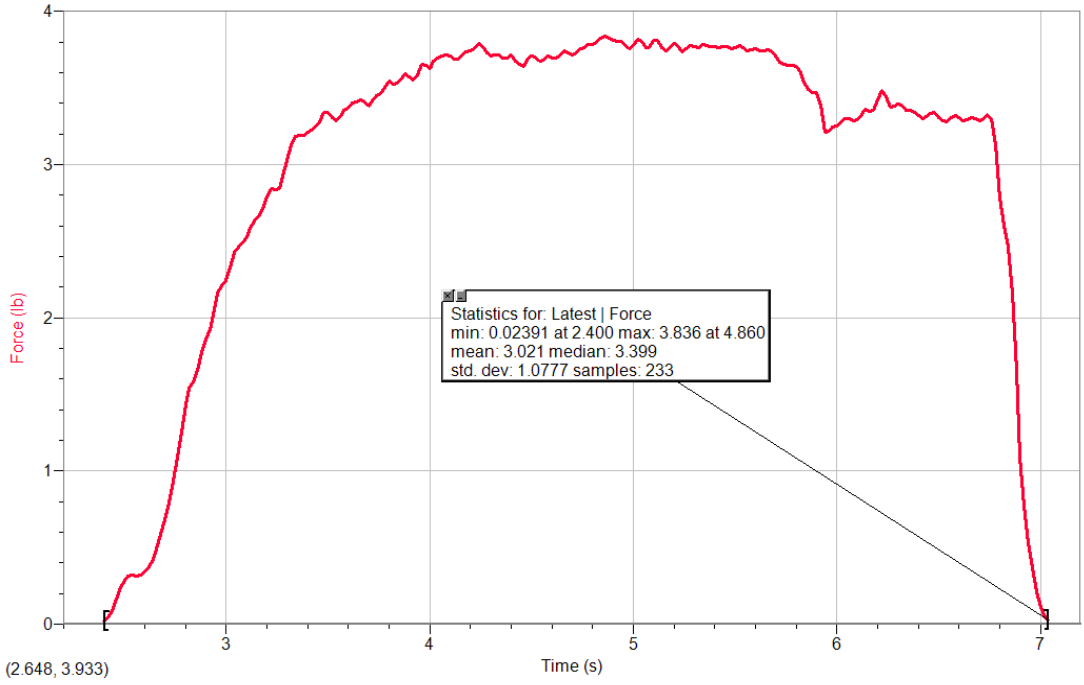
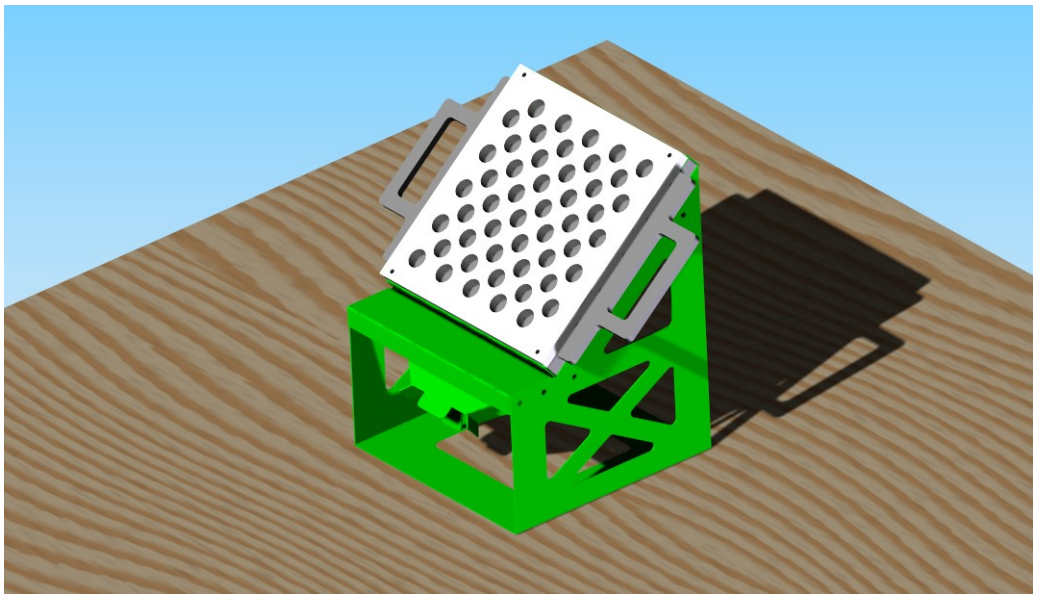

Force (lb)
Time (s)
Statistics for: Latest | Force
min: 0.02391 at 2.400 max: 3.836 at 4.860
mean: 3.021 median: 3.399
std. dev: 1.0777 samples: 233
(2.648, 3.933)

Figure C.3: Data for Sliding the Device on the Table

Appendix D: User's Manual

The Small Parts Counting and Bagging Device (SPCaBD)

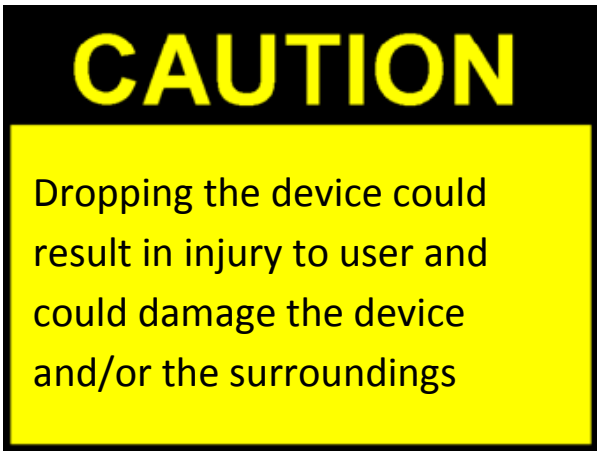
User Manual



OHIO UNIVERSITY

DANGER
Keep fingers away from device's openings to avoid injury.

CAUTION
Using this device improperly could result in harm to user and/or damage to device.


CAUTION
Dropping the device could result in injury to user and could damage the device and/or the surroundings

SPCaBD Overview

Thank you for using the small parts counter. To ensure proper use of the device please this simple manual. Figure 1 shows the part names used in this manual.

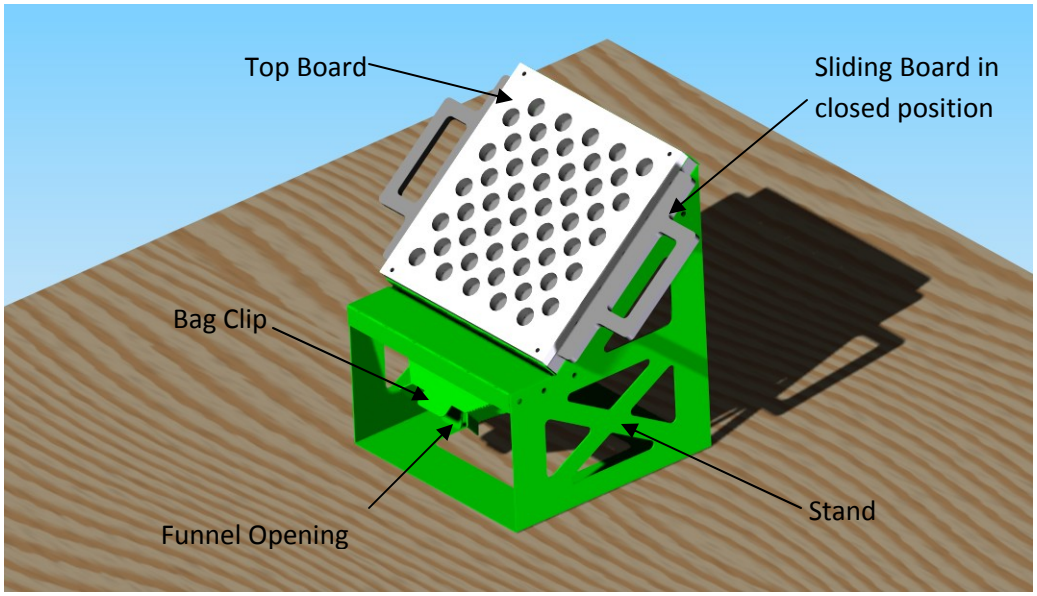


Figure 1: SPCaBD Overview

Setting Up the Device

To ensure that the device can be used safely be sure that it is set on a sturdy surface and that it is comfortable to use in a sitting position. No clamping mechanism is required though a rubber pad is recommended.

Using the Device

1. Insert the top of the bag into the bag clip at the top of the funnel opening. Make sure the bag is open all the way and the bottom side of the bag is under the funnel opening.
2. Ensure that the sliding board is in the closed position. A pair of magnets is used to lightly lock the sliding board in the closed position.
3. To get the desired number of small parts plug the unwanted holes with the provided plugs so that the desired number of parts is equal to the number of open holes.
4. Insert all your small parts into the open holes so there is one part in each hole.
5. Once all the holes are filled push or pull the sliding board form either side until it stops. All the parts will fall into the bag.
6. Remove the bag and repeat steps 1-5 for another bag or keep the bag on and repeat steps 2-5 to fill the same bag with a different type of hardware.

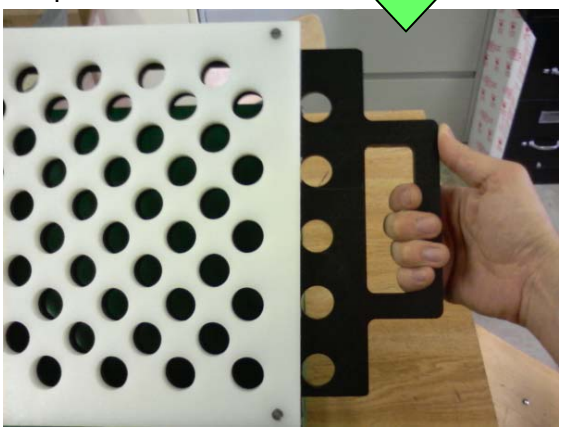
Note: Washers less than 1/8in in thickness could slide between the top board and the sliding board if placed flat on the sliding board. Washers should rest on the top board.

Using the Device (cont'd)

Steps 1-3

Step 4

Step 5



Step 6

Maintenance

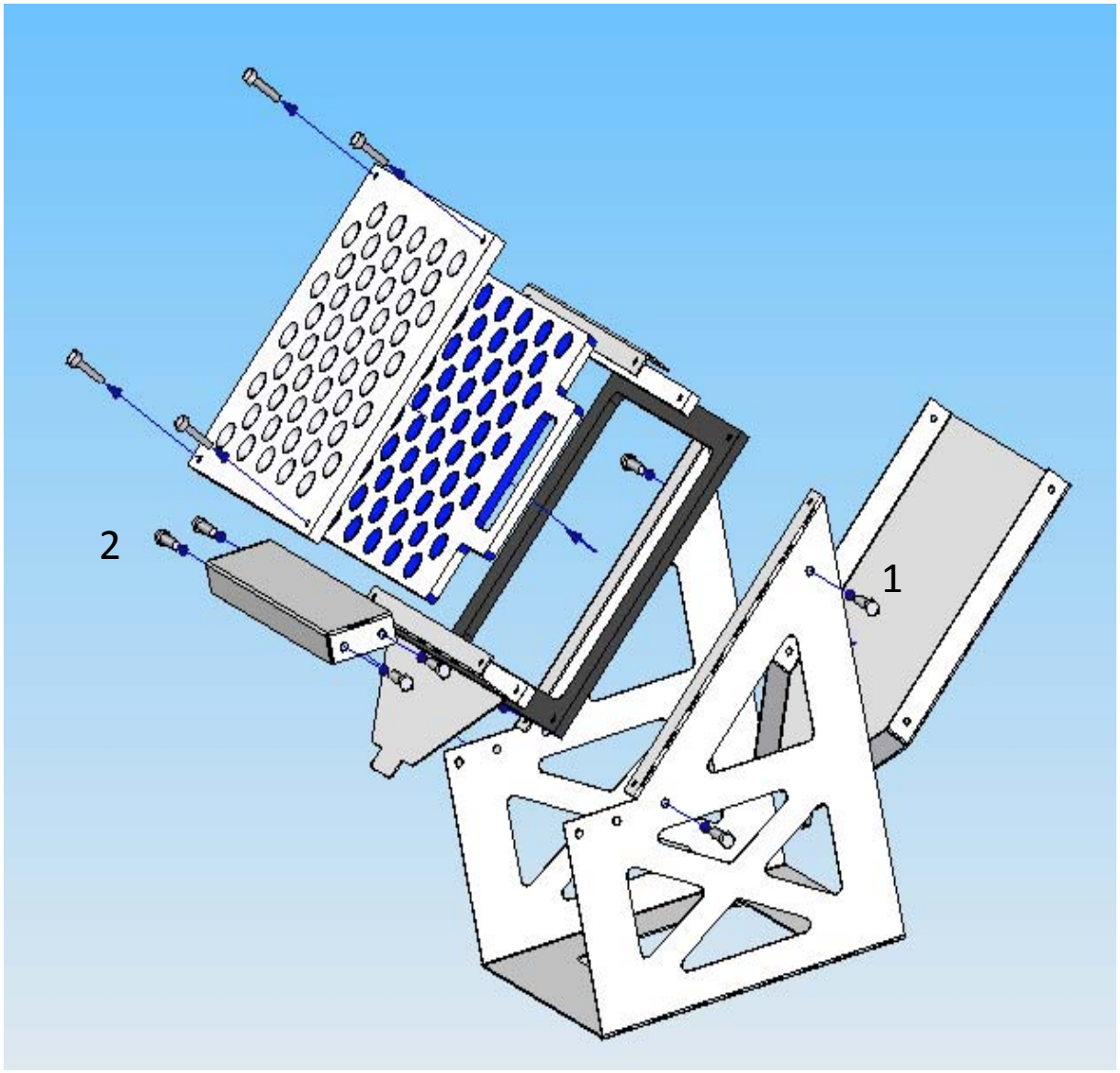
Should the device require any maintenance there is a preferred method to dissembling the device.

1. Remove four (4) blots on side of device labeled 2 and remove the catch tray.
2. Remove four (4) bolts on front of board assembly and remove board assembly one board at a time.
3. Remove four (4) bolts from side of device and remove the funnel tray.

To reassemble follow steps in reverse. This is best done with two people but can be done with one.

Tools needed:

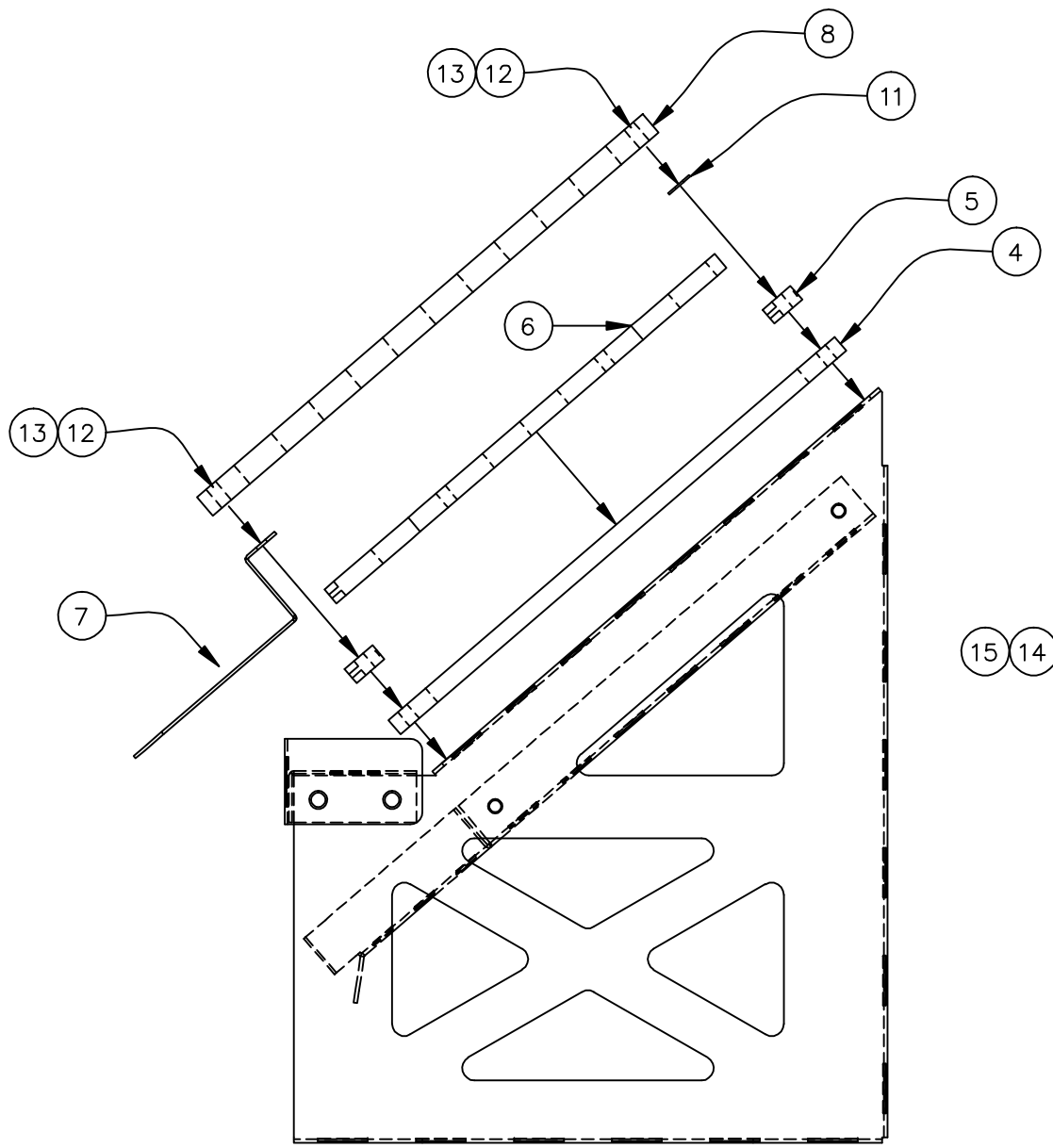
1. Flat Head Screw Driver
2. Adjustable Wrench
3. Adhesive (Polyethylene compatible)

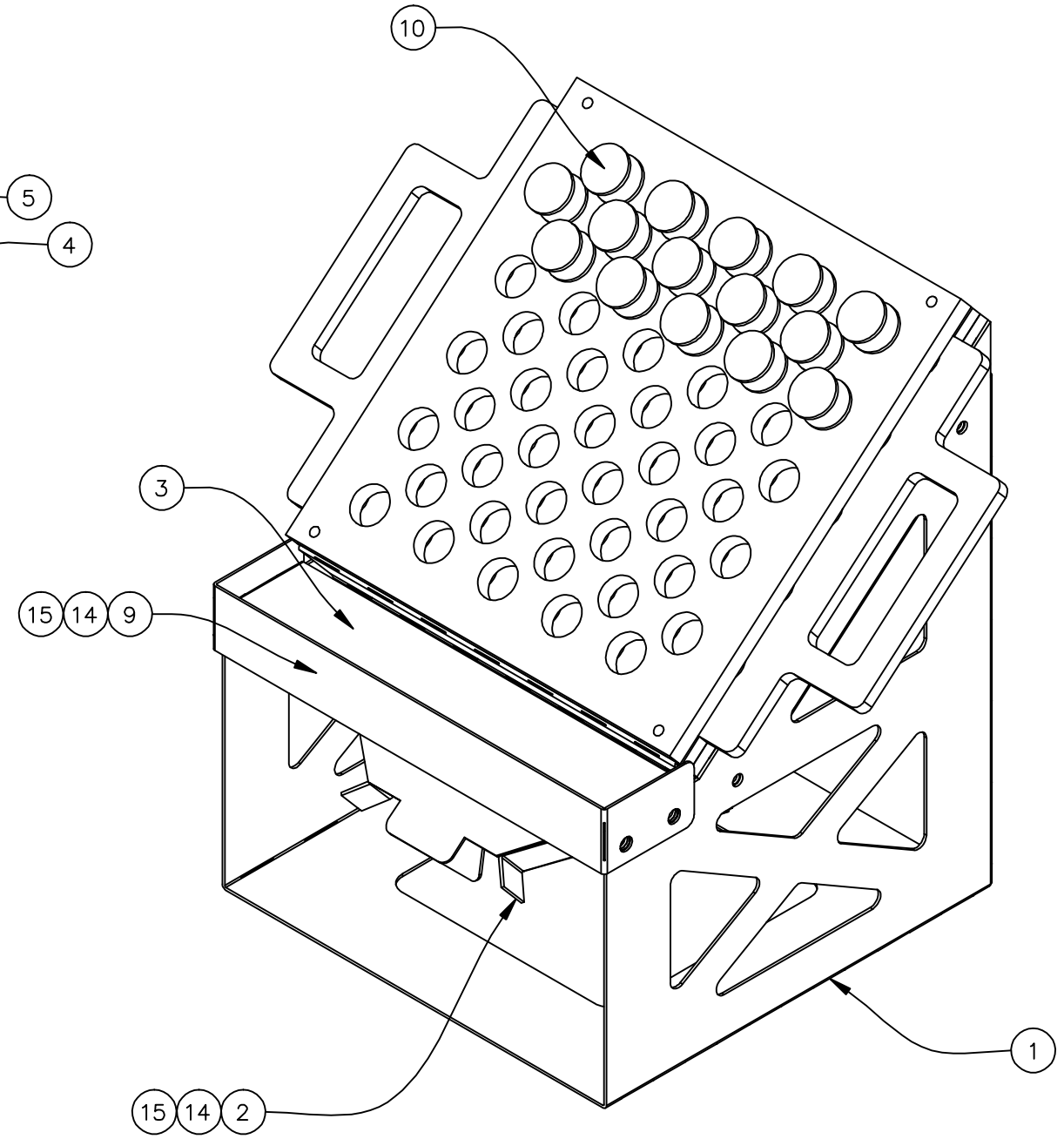

2
1

Appendix E: Design Drawings

The following pages encapsulate the design drawings that detail our product.

VIEW-A





BILL OF MATERIAL

ITEM NO.	DRAWING NO. MATERIAL	REV.	DESCRIPTION	NO. REQ'D.
1	09-002-D		STAND	1
2	09-003-D		FUNNEL TRAY	1
3	09-004-D		CATCH TRAY	1
4	09-005-D		BOTTOM BOARD	1
5	09-006-D		SPACER BAR	2
6	09-007-D		SLIDER BOARD	1
7	09-008-D		FUNNEL TRAY COVER	1
8	09-0010-D		TOP BOARD	1
9	09-0011-D		CATCH TRAY	1
10	09-0012-D		PLUG	50
11	#10 WASHER		REGULAR #10 WASHER	2
12	#10 HEX BOLT		#10-24 UNC X 2" LG. HEX HEAD BOLT	4
13	#10 HEX NUT		#10-24 UNC HEX NUT	4
14	1/4" HEX BOLT		1/4-20 UNC X 1/2" LG. HEX HEAD BOLT	8
15	1/4" HEX NUT		1/4-20 UNC HEX NUT	8
16				

NOTES:
1. SEE VIEW-A FOR ASSEMBLY ORDER
2. NOT ALL PLUGS SHOWN FOR CLARITY

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UNLESS OTHERWISE SPECIFIED DIM. TOLERANCES
FRACTIONAL ± 1/64
XX ± .100
XXX ± .010
XXXX ± .005

ALL FINISHED SURFACES 125
BREAK ALL SHARP EDGES

REVISION:							
NO.	DATE	OWNER	DESCRIPTION				
A	5/15/09	SPGEROSKI	REPLACED "BACK SUPPORT" WITH #10 WASHERS				
B	6/9/2009	SPGEROSKI	ADDED 09-012-D "PLUG"				

FLATNESS		SQUARENESS	⊥
STRAIGHTNESS	—	ANGULARITY	∠
ROUNDNESS	○	RUNOUT	↗
CYLINDRICITY	⌭	TRUE POSITION	⌖
PARALLELISM	∥	CONCENTRICITY	◎

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RUSS COLLEGE OF ENGINEERING & TECHNOLOGY
SENIOR DESIGN TEAM #8
ATHENS, OH USA

TITLE: PART COUNTER MAIN ASSEMBLY

DRAWN BY: S.GEROSKI	DATE: 1/26/2009	MATERIAL:	
SCALE: N/A	DRAWING NO: 09-001-A		REV. B
CHECKED:			

BILL OF MATERIAL

ITEM NO.	DRAWING NO. MATERIAL	REV.	DESCRIPTION	NO. REQ'D.
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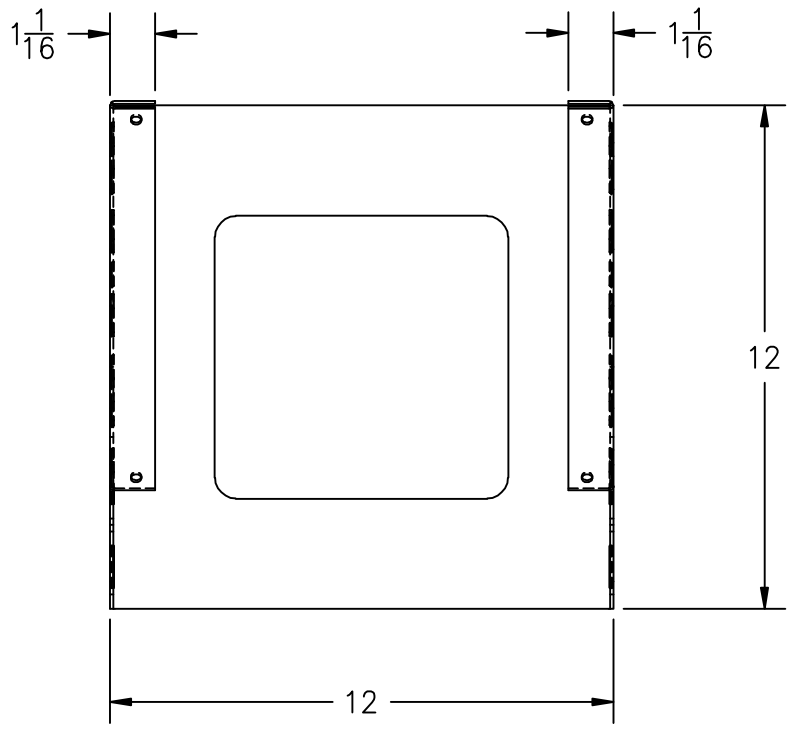
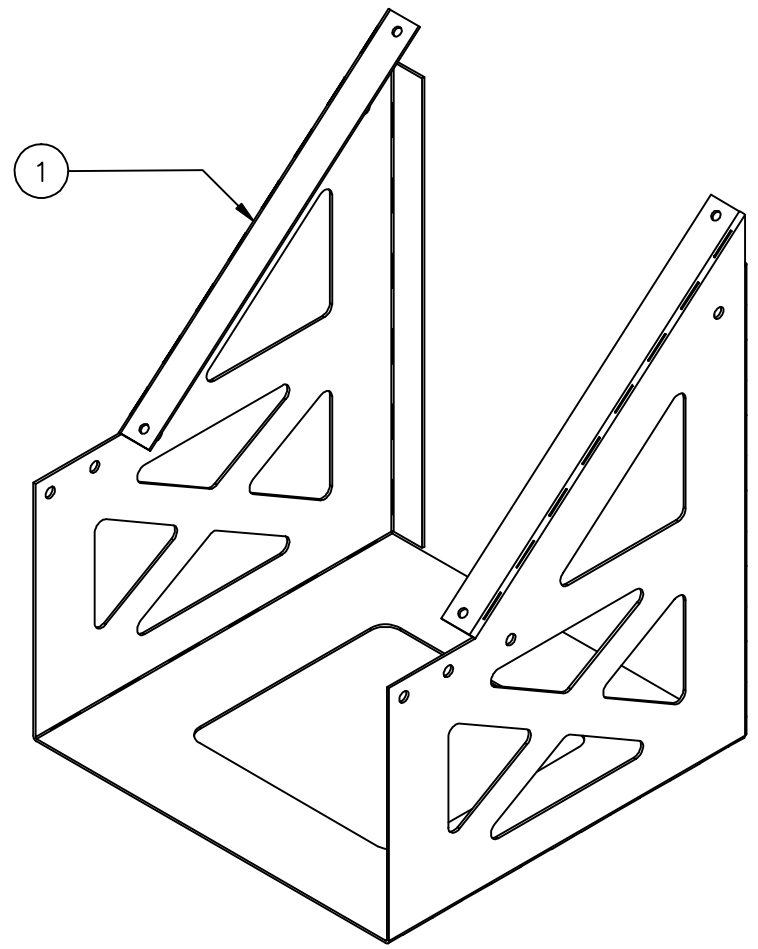
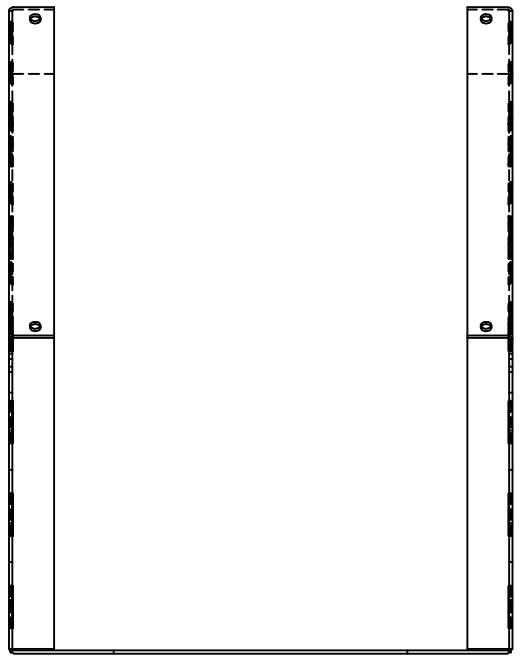
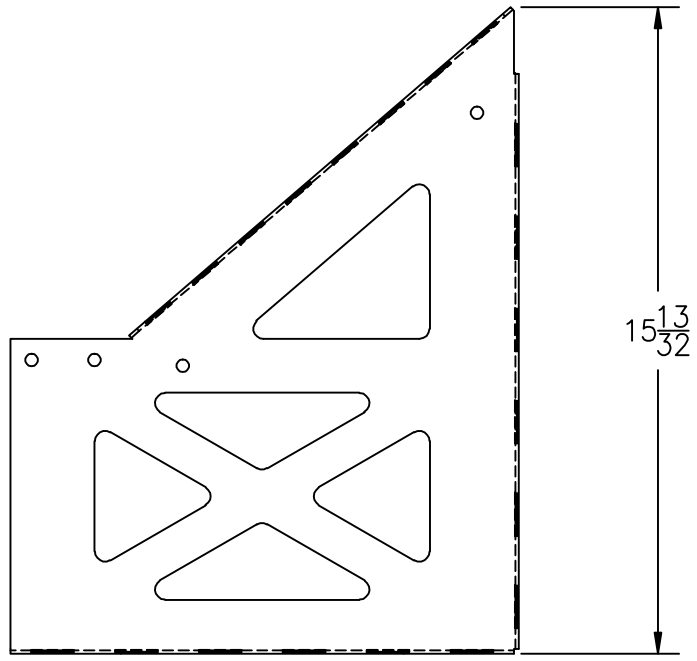
2				









NOTES:
1. BEND ON PERFORATIONS
2. PAINT GREEN

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UNLESS OTHERWISE SPECIFIED DIM. TOLERANCES
FRACTIONAL ± 1/64
X.X ± .100
X.XX ± .010
X.XXX ± .005

ALL FINISHED SURFACES 125
BREAK ALL SHARP EDGES

GD&T		GD&T	
FLATNESS	▱	SQUARENESS	⊥
STRAIGHTNESS	—	ANGULARITY	∠
ROUNDNESS	○	RUNOUT	↗
CYLINDRICITY	⌭	TRUE POSITION	⌖
PARALLELISM	∥	CONCENTRICITY	◎

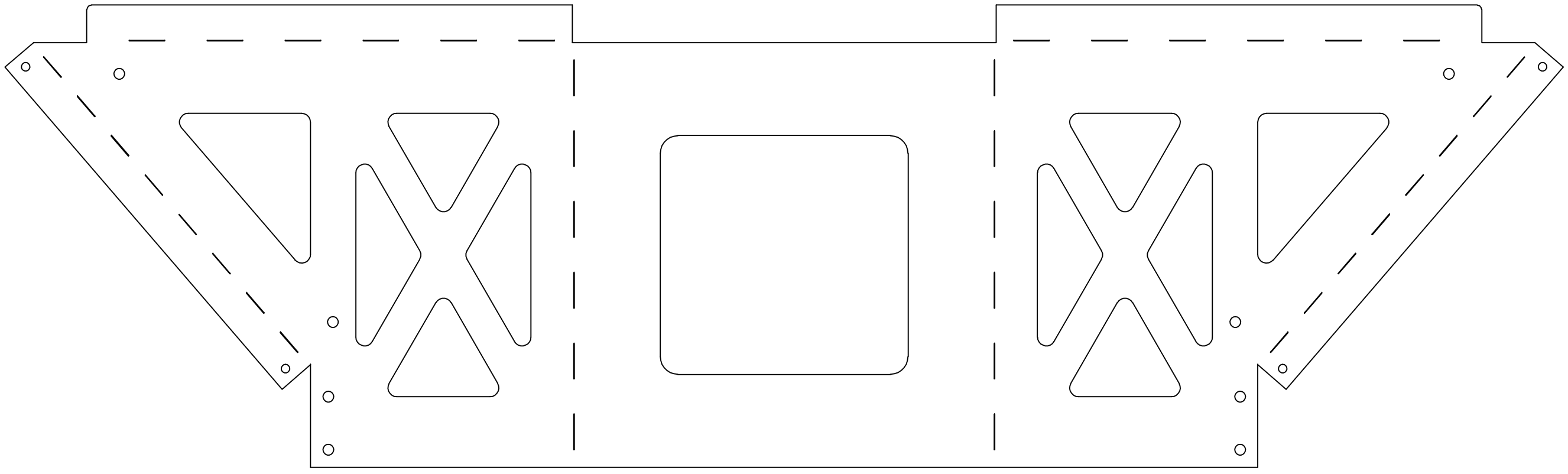
REVISION:

NO.	DATE	OWNER	DESCRIPTION
A	5/15/2009	SPGEROSKI	1. REMOVED 1" TAB FROM BACK TO ALLOW ACCESS TO INSIDE NUTS AND BOLTS 2. LOWERED FUNNEL TRAY MOUNT HOLES

OHIO UNIVERSITY
RUSS COLLEGE OF ENGINEERING & TECHNOLOGY
SENIOR DESIGN TEAM #8
ATHENS, OH USA

TITLE: STAND

DRAWN BY: S.GEROSKI	DATE: 1/26/2009	MATERIAL: 09-002-LC
SCALE: N/A	DRAWING NO: 09-002-D	REV. A
CHECKED:		



PROPRIETARY INFORMATION

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RUSS COLLEGE OF ENGINEERING & TECHNOLOGY
SENIOR DESIGN TEAM #8

UNLESS OTHERWISE SPECIFIED
DIM. TOLERANCES
FRACTONAL ± 1/64
X.X ± .100
XXX ± .010
XXXX ± .005

ALL FINISHED SURFACES 125
BREAK ALL SHARP EDGES

FLATNESS	SQUARENESS
STRAIGHTNESS	ANGULARITY
ROUNDNESS	RUNOUT
CYLINDRICITY	TRUE POSITION
PARALLELISM	CONCENTRICITY

REVISION:

NO.	DATE	OWNER	DESCRIPTION
A	5/15/2009	SPGEROSKI	1. REMOVED 1" TAB FROM BACK TO ALLOW ACCESS TO INSIDE NUTS AND BOLTS 2. LOWERED FUNNEL TRAY MOUNT HOLES

OHIO UNIVERSITY
RUSS COLLEGE OF ENGINEERING & TECHNOLOGY
SENIOR DESIGN TEAM #8
ATHENS, OH USA

TITLE: STAND

DRAWN BY: S.P.GEROSKI
DATE: 1/22/2009
MATERIAL: 14 GA. SHEET METAL
SCALE: N/A
CHECKED:
DRAWING NO: 09-002-LC
REV. A

BILL OF MATERIAL

ITEM NO.	DRAWING NO. MATERIAL	REV	DESCRIPTION	NO. REQ'D.
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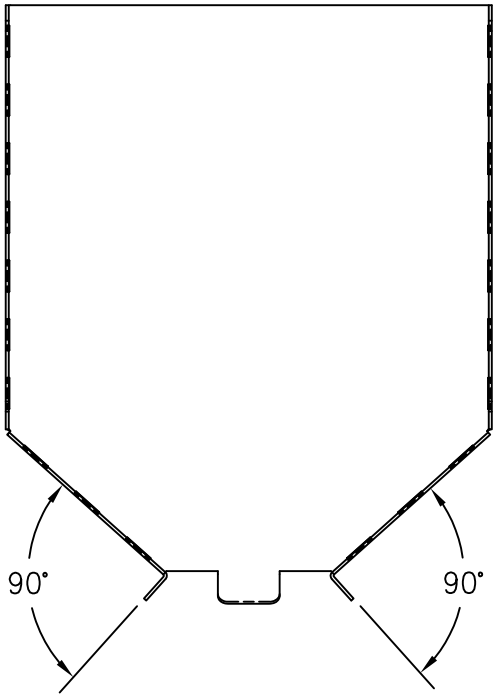
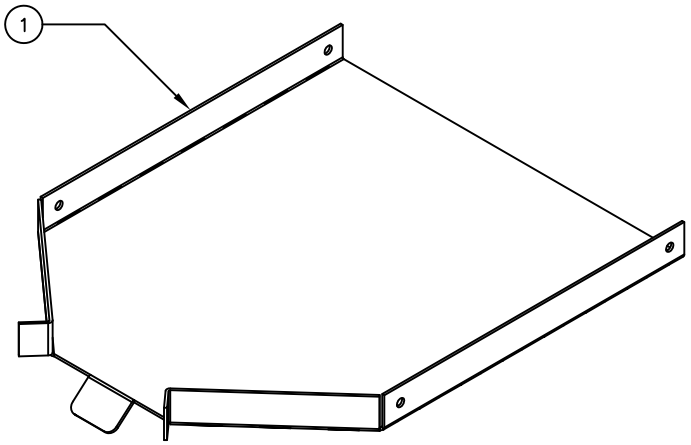
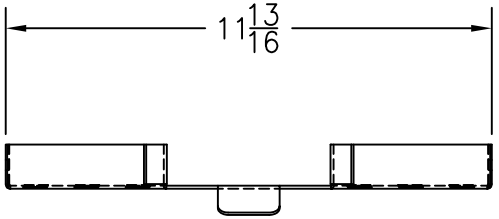
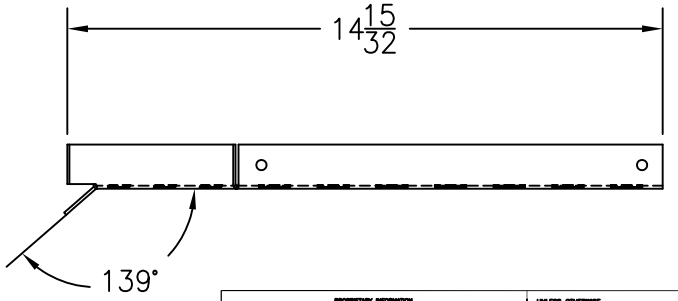
NOTES:
1. BEND ON PERFORATIONS
2. PAINT GREEN









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UNLESS OTHERWISE SPECIFIED DIM. TOLERANCES
FRACTIONAL ± 1/64
X.X ± .100
X.XX ± .030
X.XXX ± .005
ALL FINISHED SURFACES 125
BREAK ALL SHARP EDGES

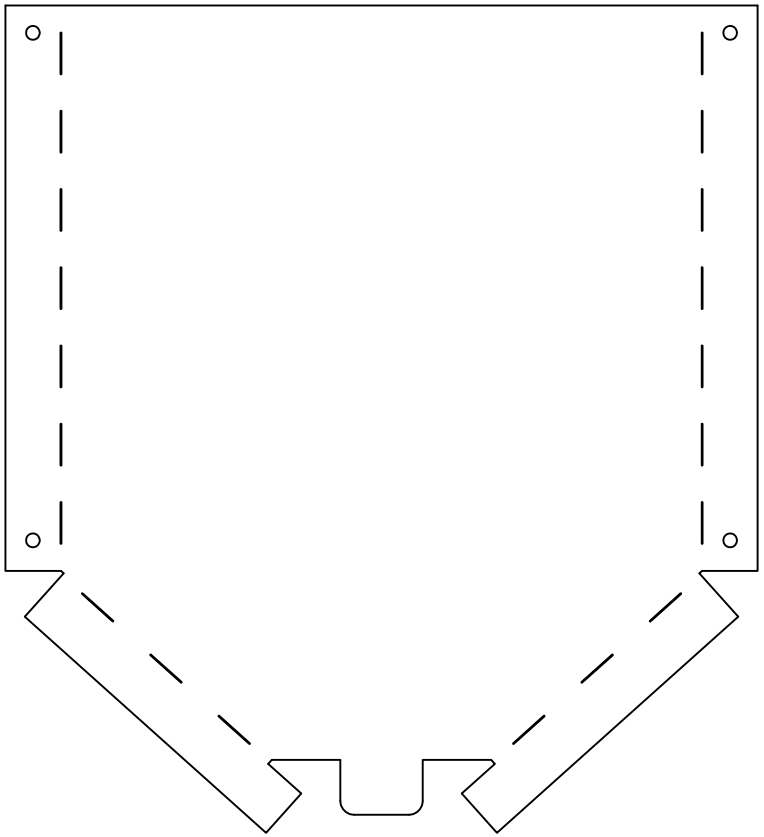
FLATNESS		SQUARENESS	⊥
STRAIGHTNESS	—	ANGULARITY	∠
ROUNDNESS	○	RUNOUT	↗
CYLINDRICITY	⌭	TRUE POSITION	⌖
PARALLELISM	∥	CONCENTRICITY	◎

REVISION: NO.	DATE	OWNER	DESCRIPTION

OHIO UNIVERSITY
RUSS COLLEGE OF ENGINEERING & TECHNOLOGY
SENIOR DESIGN TEAM #8
ATHENS, OH USA

TITLE: FUNNEL TRAY

DRAWN BY:	DATE:	MATERIAL:
S.GEROSKI	2/26/2009	09-003-LC
SCALE: N/A	DRAWING NO: 09-003-D	REV.
CHECKED:		



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UNLESS OTHERWISE SPECIFIED DIM. TOLERANCES
FRACTIONAL ± 1/64
X.X ± .100
X.XX ± .010
X.XXX ± .005

ALL FINISHED SURFACES
BREAK ALL SHARP EDGES

REVISION:			
NO.	DATE	OWNER	DESCRIPTION

FLATNESS		SQUARENESS	⊥
STRAIGHTNESS	—	ANGULARITY	∠
ROUNDNESS	○	RUNOUT	↗
CYLINDRICITY	⌭	TRUE POSITION	⌖
PARALLELISM	∥	CONCENTRICITY	◎

OHIO UNIVERSITY
RUSS COLLEGE OF ENGINEERING & TECHNOLOGY
SENIOR DESIGN TEAM #6
ATHENS, OH USA

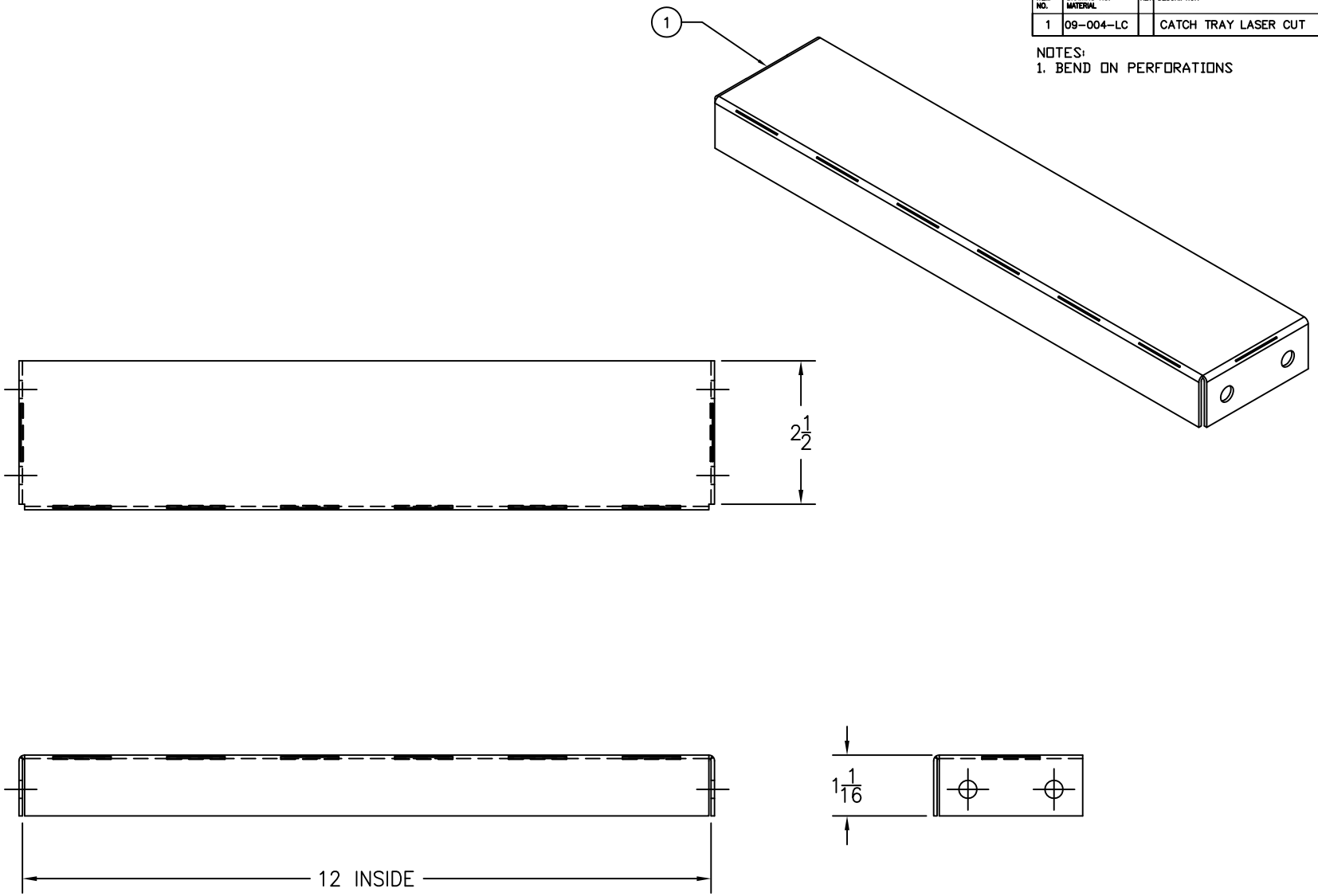
TITLE: FUNNEL TRAY

DRAWN BY: S.P.GEROSKI	DATE: 1/22/2009	MATERIAL: 16 GA. SHEET METAL	
SCALE: N/A	DRAWING NO: 09-003-LC		REV.
CHECKED:			

BILL OF MATERIAL

ITEM NO.	DRAWING NO. MATERIAL	REV	DESCRIPTION	NO. REQ'D.
1	09-004-LC		CATCH TRAY LASER CUT	1

NOTES:
1. BEND ON PERFORATIONS



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UNLESS OTHERWISE SPECIFIED DIM. TOLERANCES
FRACTIONAL ± 1/64
X.X ± .100
X.XX ± .010
X.XXX ± .005
ALL FINISHED SURFACES 125
BREAK ALL SHARP EDGES

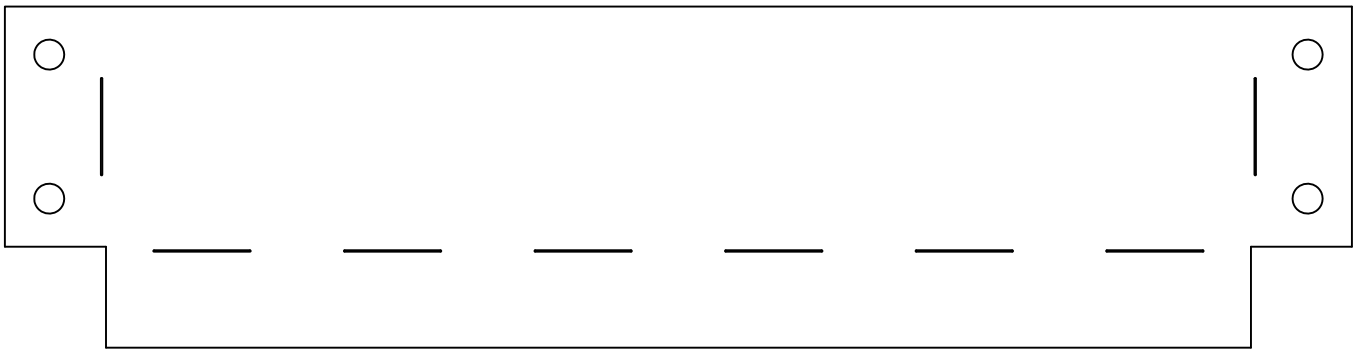
REVISION: NO.	DATE	OWNER	DESCRIPTION

FLATNESS		SQUARENESS	⊥
STRAIGHTNESS	—	ANGULARITY	∠
ROUNDNESS	○	RUNOUT	↗
CYLINDRICITY	⌭	TRUE POSITION	⌖
PARALLELISM	∥	CONCENTRICITY	◎

OHIO UNIVERSITY
RUSS COLLEGE OF ENGINEERING & TECHNOLOGY
SENIOR DESIGN TEAM #9
ATHENS, OH USA

TITLE: CATCH TRAY

DRAWN BY: S.GEROSKI
DATE: 2-29-2009
MATERIAL: 09-004-LC
SCALE: N/A
CHECKED:
DRAWING NO: 09-004-D
REV.



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UNLESS OTHERWISE SPECIFIED
DIM. TOLERANCES
FRACTIONAL ± 1/64
X.X ± .100
X.XX ± .010
X.XXX ± .005

ALL FINISHED SURFACES
BREAK ALL SHARP EDGES

REVISION:				
NO.	DATE	OWNER	DESCRIPTION	

FLATNESS		SQUARENESS	⊥
STRAIGHTNESS	—	ANGULARITY	∠
ROUNDNESS	○	RUNOUT	↗
CYLINDRICITY	⌭	TRUE POSITION	⌖
PARALLELISM	∥	CONCENTRICITY	◎

OHIO UNIVERSITY
RUSS COLLEGE OF ENGINEERING & TECHNOLOGY
SENIOR DESIGN TEAM #6
ATHENS, OH USA

TITLE: CATCH TRAY

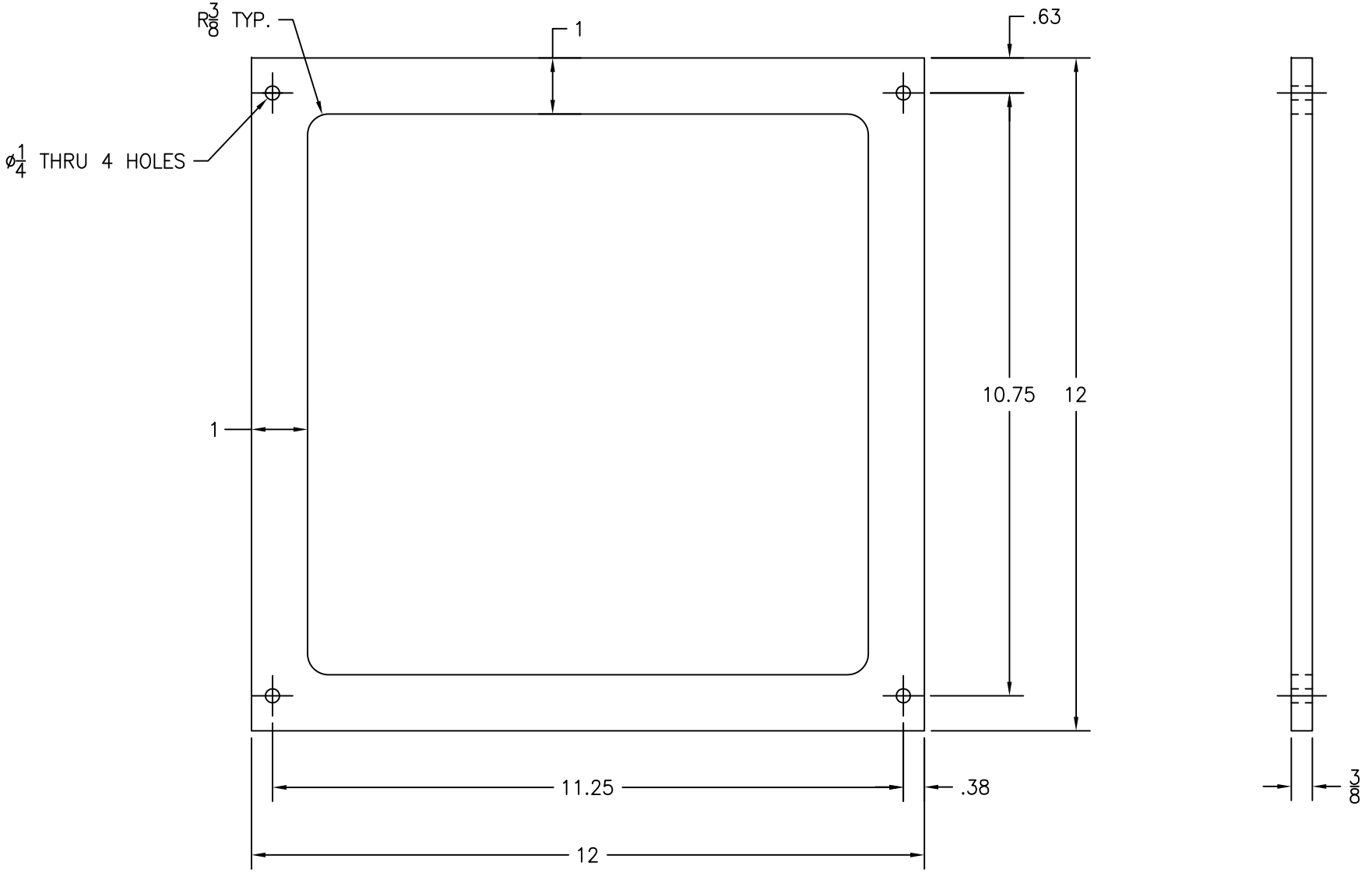
DRAWN BY:	DATE:	MATERIAL:
S.P.GEROSKI	1/22/2009	16 GA. SHEET METAL

SCALE:	DRAWING NO:	REV.
N/A	D-003-LC	

CHECKED:

BILL OF MATERIAL

ITEM NO.	DRAWING NO. MATERIAL	REV	DESCRIPTION	NO. REQ'D.



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UNLESS OTHERWISE SPECIFIED DIM. TOLERANCES
FRACTIONAL ± 1/64
X.X ± .100
X.XX ± .010
X.XXX ± .005

ALL FINISHED SURFACES
BREAK ALL SHARP EDGES

REVISION: NO.	DATE	OWNER	DESCRIPTION

FLATNESS		SQUARENESS	⊥
STRAIGHTNESS	—	ANGULARITY	∠
ROUNDNESS	○	RUNOUT	↗
CYLINDRICITY	⌭	TRUE POSITION	⌖
PARALLELISM	∥	CONCENTRICITY	◎

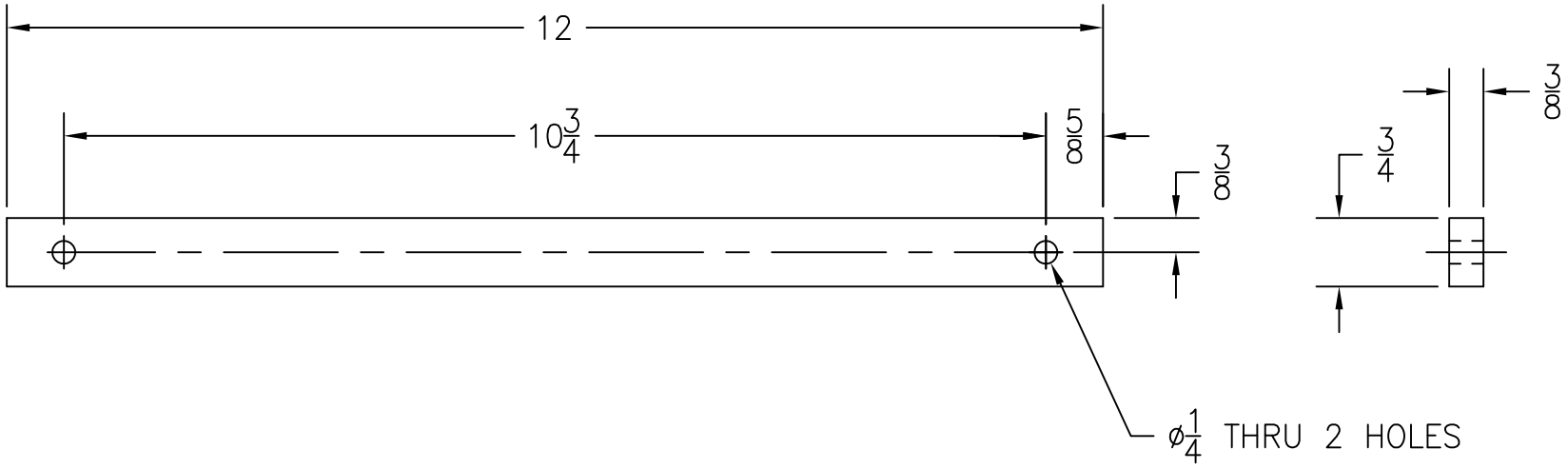
OHIO UNIVERSITY
RUSS COLLEGE OF ENGINEERING & TECHNOLOGY
SENIOR DESIGN TEAM #8
ATHENS, OH USA

TITLE: BOTTOM BOARD

DRAWN BY: S.GEROSKI	DATE: 3/5/2009	MATERIAL: 3/8" THICK UHMW	
SCALE: N/A	DRAWING NO: 09-005-D		REV.
CHECKED:			

BILL OF MATERIAL

ITEM NO.	DRAWING NO. MATERIAL	REV	DESCRIPTION	NO. REQ'D.



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UNLESS OTHERWISE SPECIFIED DIM. TOLERANCES
FRACTIONAL ± 1/64
X.X ± .100
X.XX ± .010
X.XXX ± .005

ALL FINISHED SURFACES
BREAK ALL SHARP EDGES

REVISION:			
NO.	DATE	OWNER	DESCRIPTION

FLATNESS		SQUARENESS	⊥
STRAIGHTNESS	—	ANGULARITY	∠
ROUNDNESS	○	RUNOUT	↗
CYLINDRICITY	⌭	TRUE POSITION	⌖
PARALLELISM	∥	CONCENTRICITY	◎

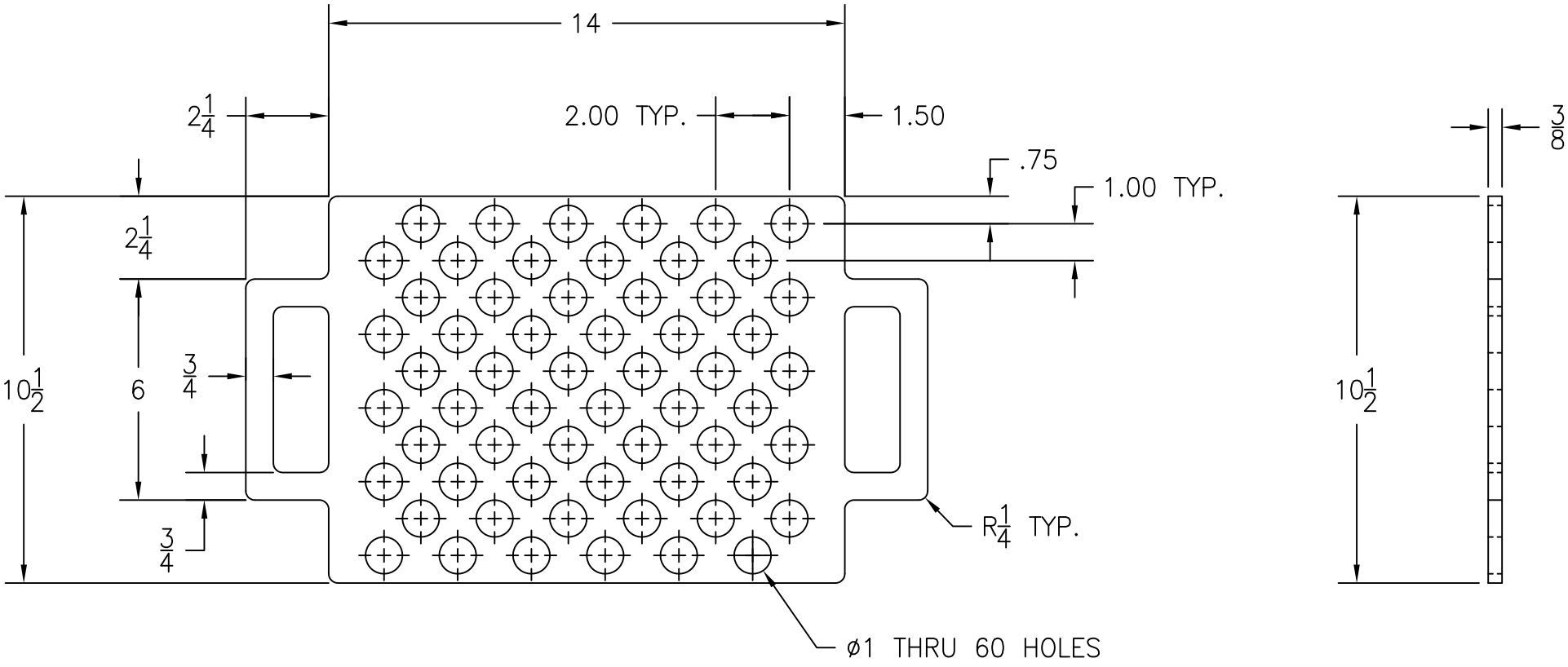
OHIO UNIVERSITY
RUSS COLLEGE OF ENGINEERING & TECHNOLOGY
SENIOR DESIGN TEAM #8
ATHENS, OH USA

TITLE: SPACER BAR

DRAWN BY:	DATE:	MATERIAL:
S.GEROSKI	3/16/2009	3/8" X 3/4" X 12" UHMW
SCALE: N/A	DRAWING NO: 09-006-D	REV.
CHECKED:		

BILL OF MATERIAL

ITEM NO.	DRAWING NO. MATERIAL	REV	DESCRIPTION	NO. REQ'D.



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UNLESS OTHERWISE SPECIFIED DIM. TOLERANCES
FRACTIONAL ± 1/64
X.X ± .100
X.XX ± .010
X.XXX ± .005
ALL FINISHED SURFACES
BREAK ALL SHARP EDGES

REVISION:			
NO.	DATE	OWNER	DESCRIPTION

FLATNESS		SQUARENESS	⊥
STRAIGHTNESS	—	ANGULARITY	∠
ROUNDNESS	○	RUNOUT	↗
CYLINDRICITY	⌭	TRUE POSITION	⌖
PARALLELISM	∥	CONCENTRICITY	◎

OHIO UNIVERSITY
RUSS COLLEGE OF ENGINEERING & TECHNOLOGY
SENIOR DESIGN TEAM #8
ATHENS, OH USA

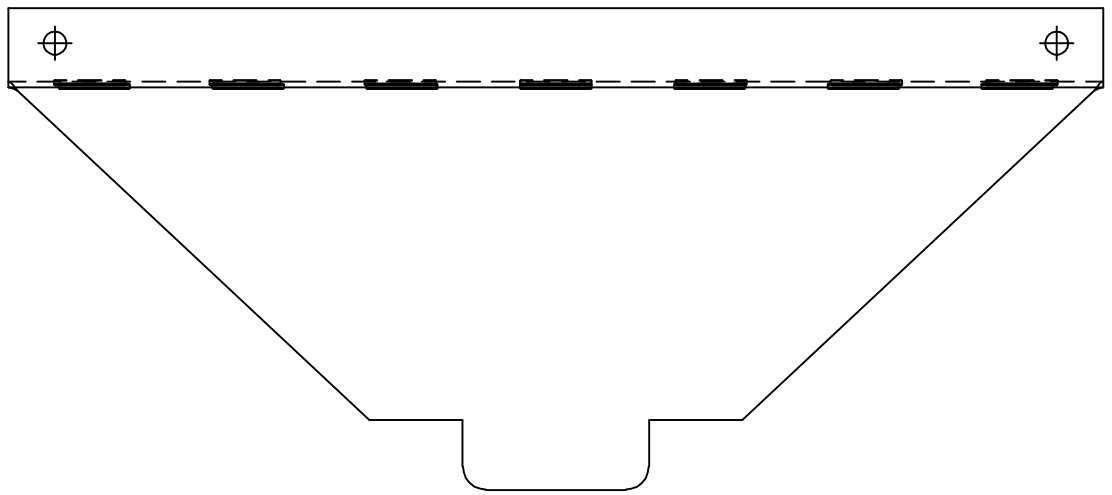
TITLE: SLIDER BOARD

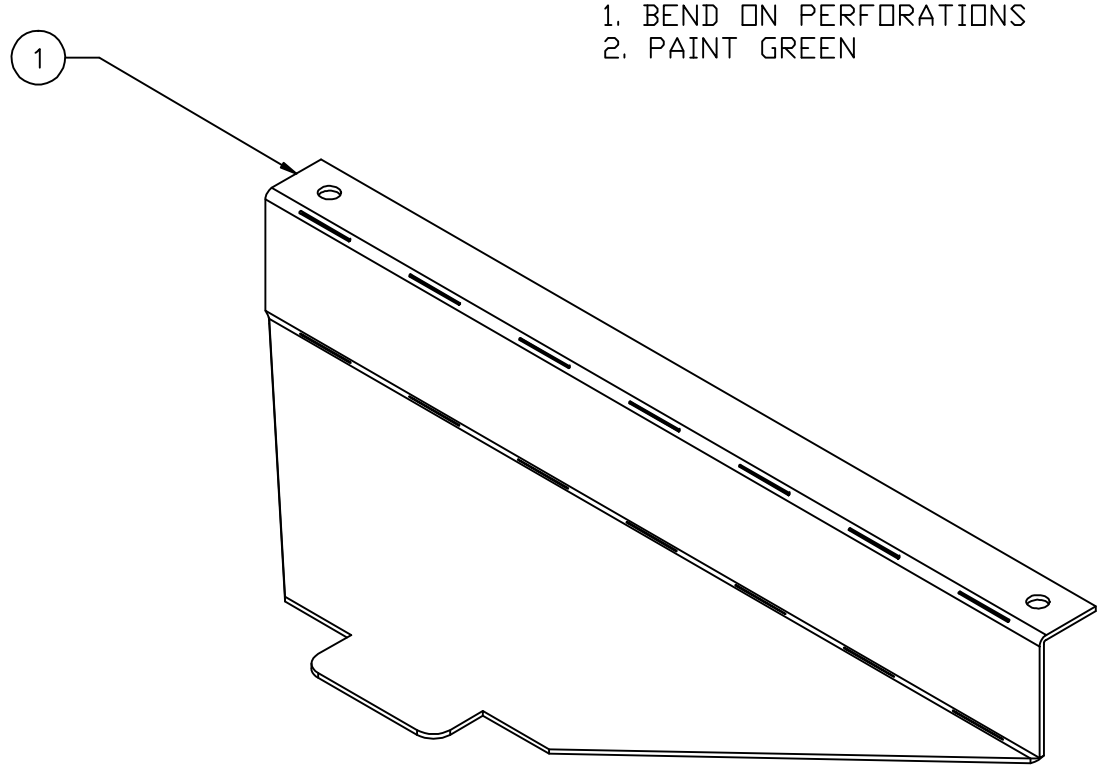
DRAWN BY:	DATE:	MATERIAL:
S.GEROSKI	3/16/2009	3/8" X 18-1/2" X 10-1/2" UHMW
SCALE: N/A	DRAWING NO: 09-007-D	REV.
CHECKED:		

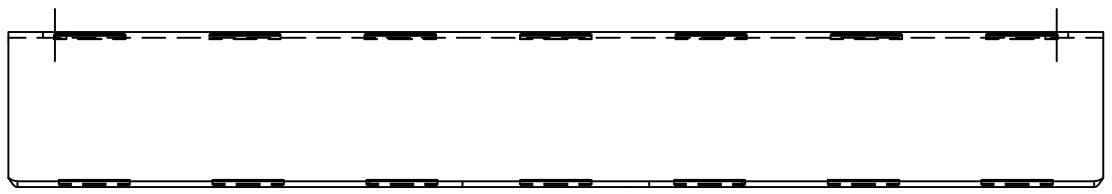
BILL OF MATERIAL

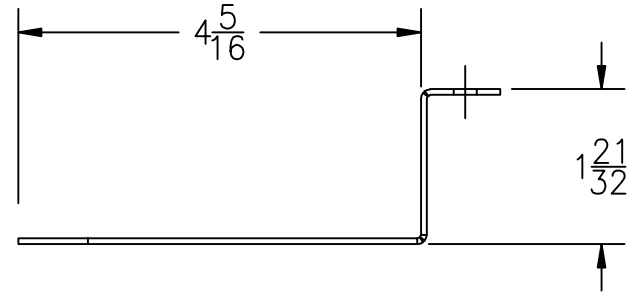
ITEM NO.	DRAWING NO. MATERIAL	REV.	DESCRIPTION	NO. REQ'D.
1	09-008-LC		FUNNEL TRAY COVER LASER CUT	1

NOTES:
1. BEND ON PERFORATIONS
2. PAINT GREEN









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UNLESS OTHERWISE SPECIFIED DIM. TOLERANCES
FRACTONAL ± 1/64
XX ± .100
XXX ± .010
XXXX ± .005

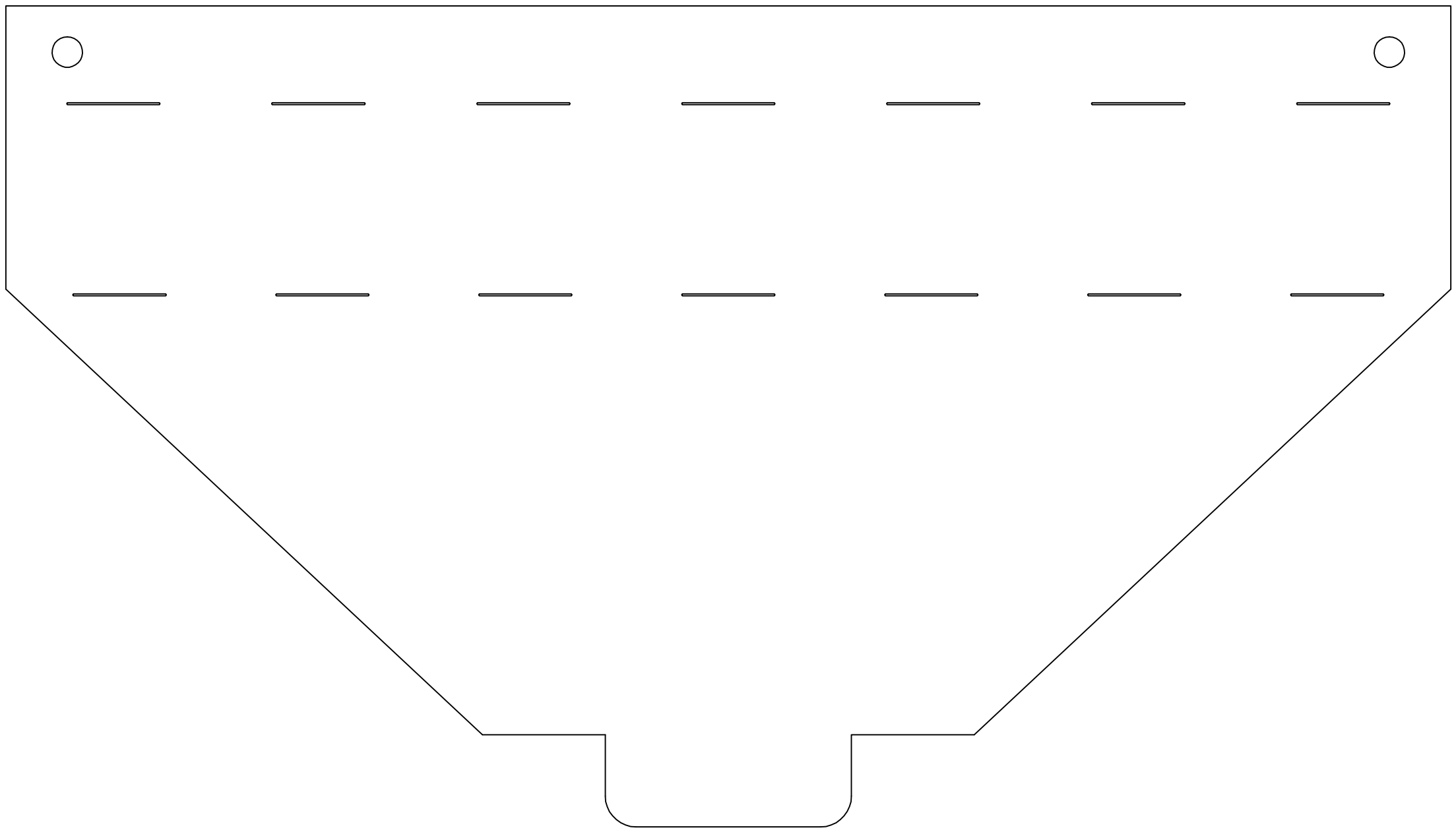
ALL FINISHED SURFACES 125
BREAK ALL SHARP EDGES

REVISION:							
NO.	DATE	OWNER	DESCRIPTION	FLATNESS	SQUARENESS		
A	5/15/2009	SPGEROSKI	INCREASED LENGHT OF VERTICAL TAB .25	STRAIGHTNESS	ANGULARITY		
				ROUNDNESS	RUNOUT		
				CYLINDRICITY	TRUE POSITION		
				PARALLELISM	CONCENTRICITY		

OHIO UNIVERSITY
RUSS COLLEGE OF ENGINEERING & TECHNOLOGY
SENIOR DESIGN TEAM #8
ATHENS, OH USA

TITLE: FUNNEL TRAY COVER

DRAWN BY: S.GEROSKI
DATE: 3/16/2008
MATERIAL: 09-008-LC
SCALE: N/A
CHECKED:
DRAWING NO: 09-008-D
REV. A



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RUSS COLLEGE OF ENGINEERING & TECHNOLOGY
SENIOR DESIGN TEAM #8

UNLESS OTHERWISE SPECIFIED
DIM. TOLERANCES
FRACTONAL ± 1/64
XX ± .100
XXX ± .010
XXXX ± .005

ALL FINISHED SURFACES 125
BREAK ALL SHARP EDGES

REVISION:			
NO.	DATE	OWNER	DESCRIPTION
A	5/15/2008	SPGEROSKI	INCREASED LENGHT OF VERTICAL TAB .25"

FLATNESS		SQUARENESS	⊥
STRAIGHTNESS	—	ANGULARITY	∠
ROUNDNESS	○	RUNOUT	↗
CYLINDRICITY	⌭	TRUE POSITION	⌖
PARALLELISM	∥	CONCENTRICITY	◎

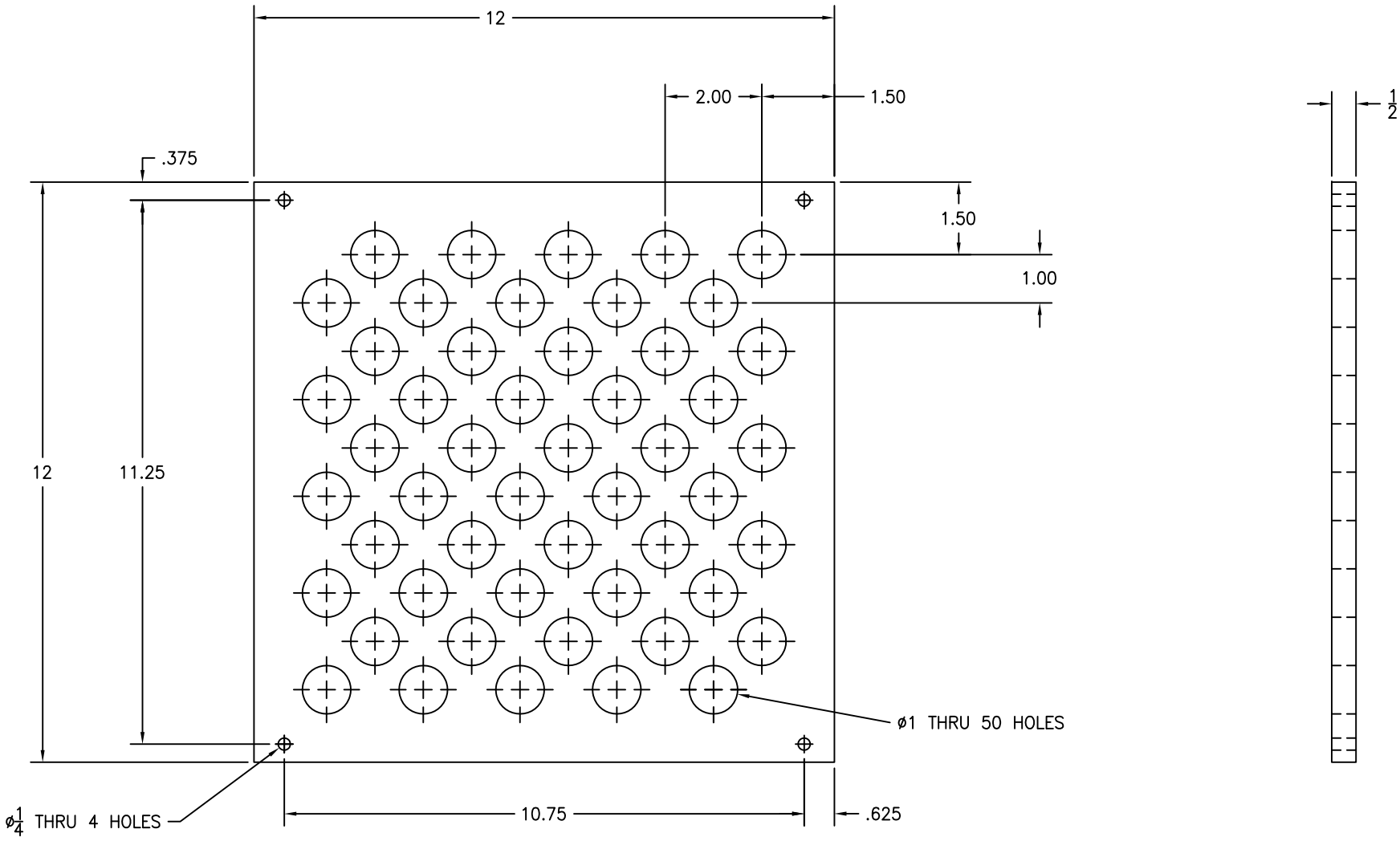
OHIO UNIVERSITY
RUSS COLLEGE OF ENGINEERING & TECHNOLOGY
SENIOR DESIGN TEAM #8
ATHENS, OH USA

TITLE: FUNNEL TRAY COVER LASER CUT

DRAWN BY: S.GEROSKI
DATE: 3/16/2008
MATERIAL: 16 GA SHEET METAL
SCALE: N/A
CHECKED:
DRAWING NO: 09-008-LC
REV. A

BILL OF MATERIAL

ITEM NO.	DRAWING NO. MATERIAL	REV	DESCRIPTION	NO. REQ'D.



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UNLESS OTHERWISE SPECIFIED DIM. TOLERANCES
FRACTIONAL ± 1/64
X.X ± .100
X.XX ± .010
X.XXX ± .005

ALL FINISHED SURFACES
BREAK ALL SHARP EDGES

REVISION:			
NO.	DATE	OWNER	DESCRIPTION

FLATNESS	▱	SQUARENESS	⊥
STRAIGHTNESS	—	ANGULARITY	∠
ROUNDNESS	○	RUNOUT	↗
CYLINDRICITY	⌭	TRUE POSITION	⌖
PARALLELISM	∥	CONCENTRICITY	◎

OHIO UNIVERSITY
RUSS COLLEGE OF ENGINEERING & TECHNOLOGY
SENIOR DESIGN TEAM #8
ATHENS, OH USA

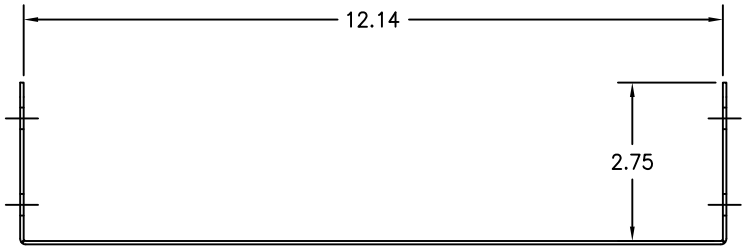
TITLE: TOP BOARD

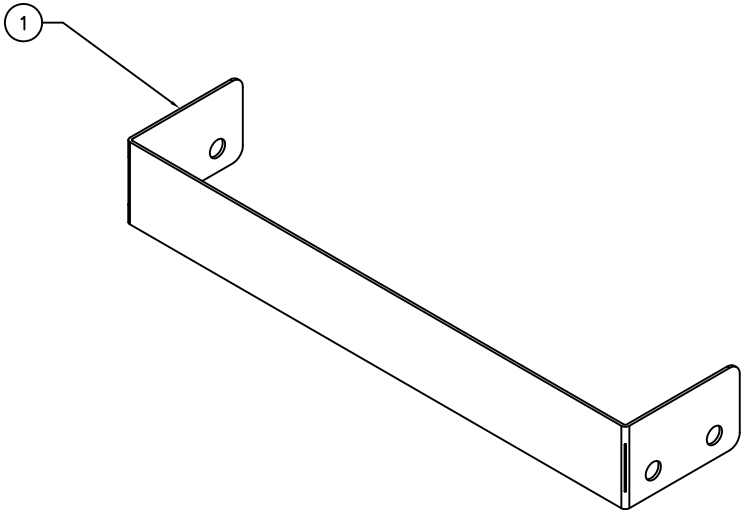
DRAWN BY:	DATE:	MATERIAL:
S.GEROSKI	3/16/2009	1/2" X 12" X 12" UHMW
SCALE: N/A	DRAWING NO: 09-010-D	REV.
CHECKED:		

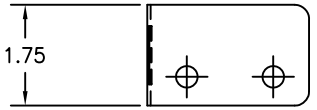
BILL OF MATERIAL

ITEM NO.	DRAWING NO. MATERIAL	REV	DESCRIPTION	NO. REQ'D.
1	09-011-LC		CATCH TRAY COVER LASER CUT	1

NOTES:
1. BEND ON PERFORATIONS
2. PAINT GREEN







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UNLESS OTHERWISE SPECIFIED DIM. TOLERANCES
FRACTIONAL ± 1/64
X.X ± .100
X.XX ± .010
X.XXX ± .005
ALL FINISHED SURFACES
BREAK ALL SHARP EDGES

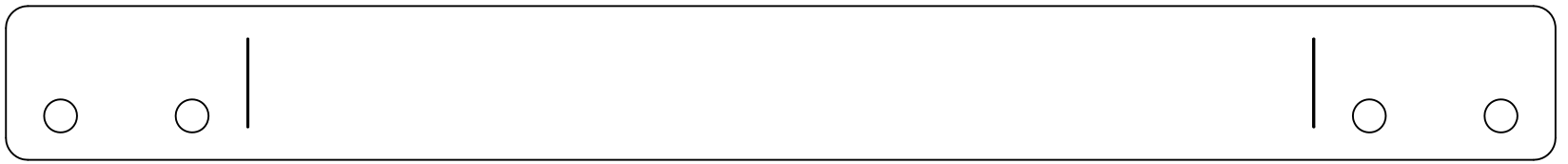
REVISION: NO.	DATE	OWNER	DESCRIPTION

FLATNESS		SQUARENESS	⊥
STRAIGHTNESS	—	ANGULARITY	∠
ROUNDNESS	○	RUNOUT	↗
CYLINDRICITY	⌭	TRUE POSITION	⌖
PARALLELISM	∥	CONCENTRICITY	◎

OHIO UNIVERSITY
RUSS COLLEGE OF ENGINEERING & TECHNOLOGY
SENIOR DESIGN TEAM #8
ATHENS, OH USA

TITLE: CATCH TRAY COVER

DRAWN BY: S.GEROSKI
DATE: 3/16/2009
MATERIAL: 09-011-LC
SCALE: N/A
CHECKED:
DRAWING NO: 09-011-D
REV.



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UNLESS OTHERWISE SPECIFIED
DIM. TOLERANCES
FRACTIONAL ± 1/64
X.X ± .02
X.XX ± .010
X.XXX ± .005

ALL FINISHED SURFACES
BREAK ALL SHARP EDGES

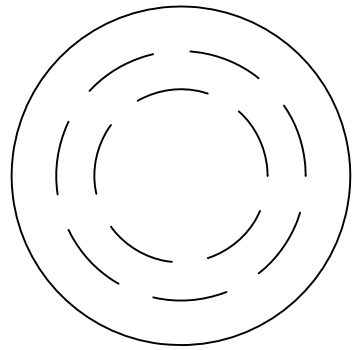
REVISION:			
NO.	DATE	OWNER	DESCRIPTION

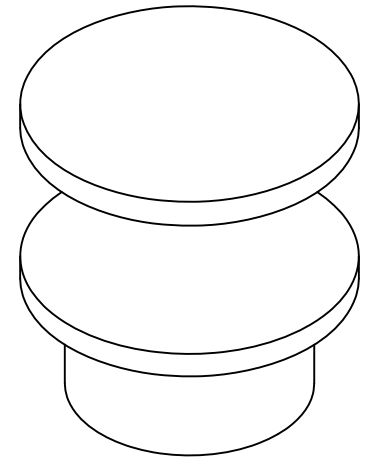
FLATNESS		SQUARENESS	⊥
STRAIGHTNESS	—	ANGULARITY	∠
ROUNDNESS	○	RUNOUT	↗
CYLINDRICITY	⌭	TRUE POSITION	⌖
PARALLELISM	∥	CONCENTRICITY	◎

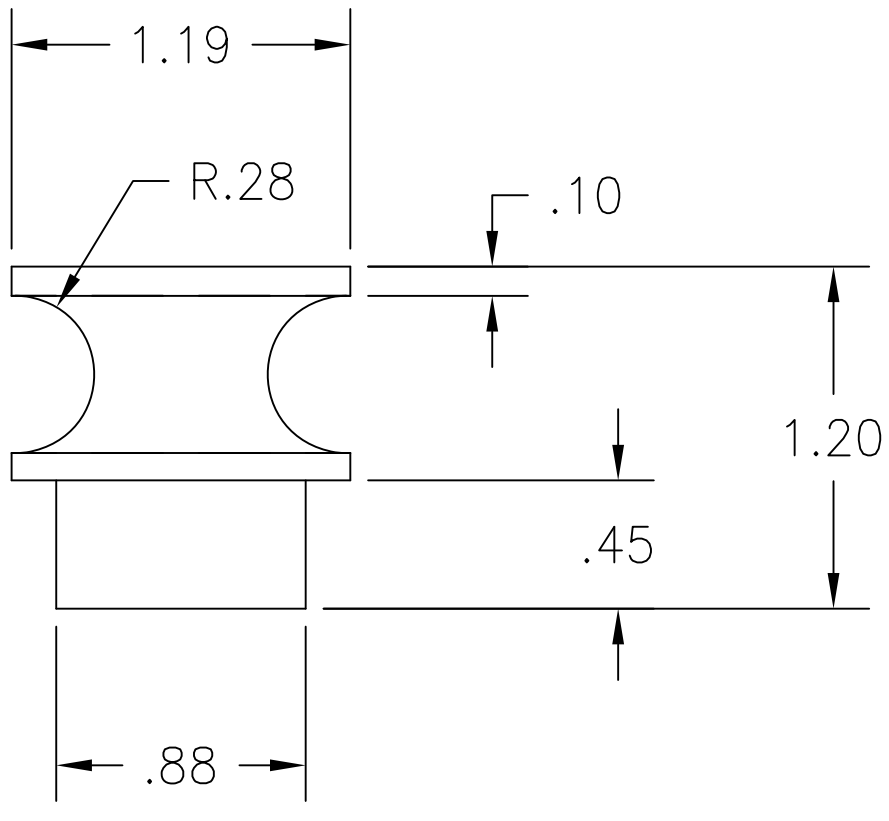
OHIO UNIVERSITY
RUSS COLLEGE OF ENGINEERING & TECHNOLOGY
SENIOR DESIGN TEAM #8
ATHENS, OH USA

TITLE: CATCH TRAY COVER LASER CUT

DRAWN BY: S.GEROSKI	DATE: 3/16/2009	MATERIAL: 16 GA. SHEET METAL	
SCALE: N/A	DRAWING NO: 09-011-LC		REV.
CHECKED:			







PROPRIETARY INFORMATION

DATA ENCLOSED HEREIN IS NOT TO BE DISCLOSED, USED OR DUPLICATED FOR ANY PURPOSE EXCEPT AS AUTHORIZED IN WRITING BY: OHIO UNIVERSITY RUSS COLLEGE OF ENGINEERING & TECHNOLOGY SENIOR DESIGN TEAM #8

UNLESS OTHERWISE SPECIFIED
DIM. TOLERANCES

FRACTIONAL ± 1/64
X.X ± .100
X.XX ± .010
X.XXX ± .005

ALL FINISHED SURFACES 125

BREAK ALL SHARP EDGES

REVISION:			
NO.	DATE	OWNER	DESCRIPTION

FLATNESS	▱	SQUARENESS	⊥
STRAIGHTNESS	—	ANGULARITY	∠
ROUNDNESS	○	RUNOUT	↗
CYLINDRICITY	⌭	TRUE POSITION	⌖
PARALLELISM	∥	CONCENTRICITY	◎

OHIO UNIVERSITY
RUSS COLLEGE OF ENGINEERING & TECHNOLOGY
SENIOR DESIGN TEAM #8
ATHENS, OH USA

TITLE: PLUG

DRAWN BY:	DATE:	MATERIAL:
K.SINK	6/9/2009	UHMW

SCALE:	DRAWING NO:	REV.
N/A	09-012-D	

CHECKED: